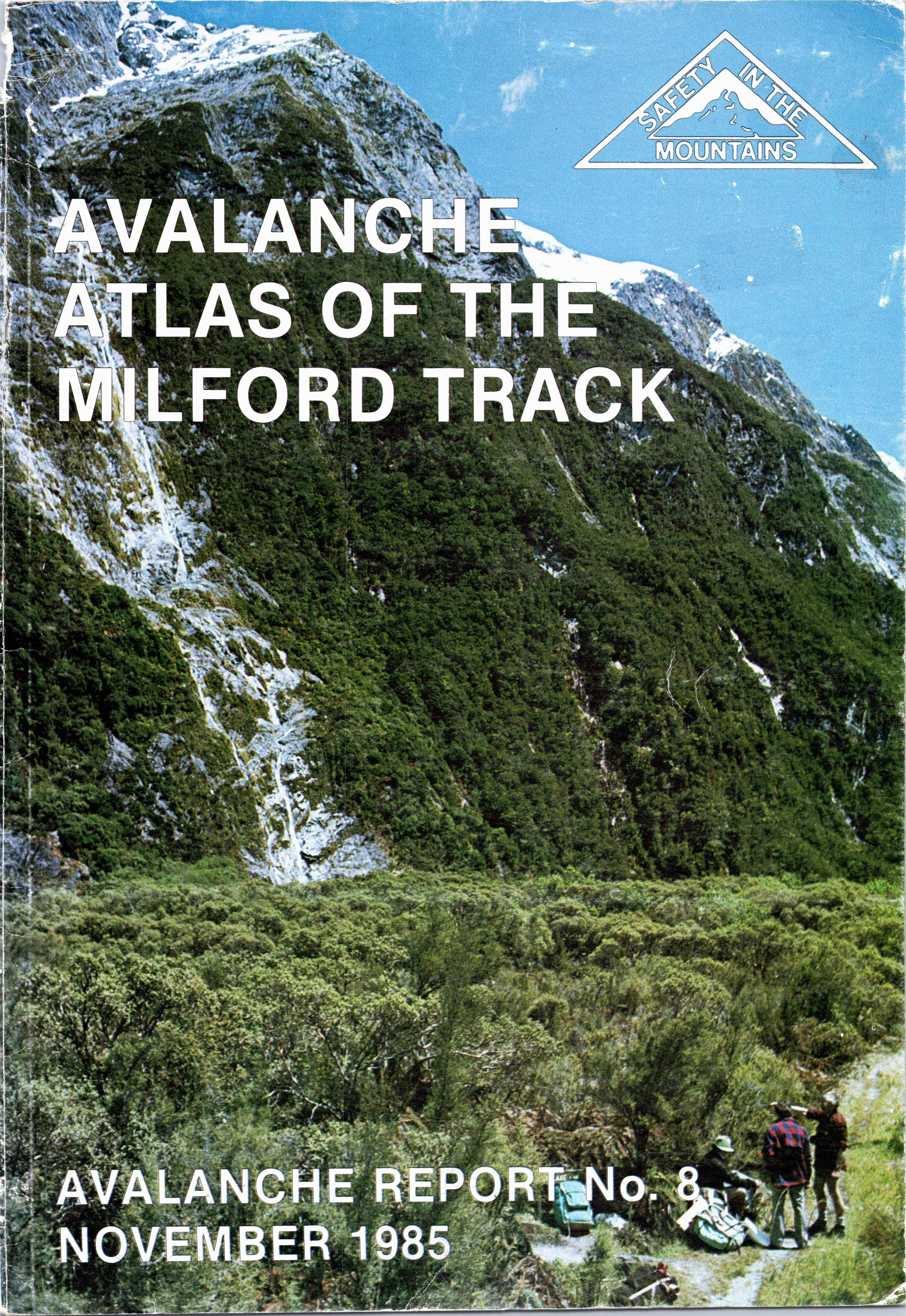

SAFETY IN THE MOUNTAINS

AVALANCHE ATLAS OF THE MILFORD TRACK

AVALANCHE REPORT No. 8

NOVEMBER 1985

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N.Z. Mountain Safety Council Avalanche Report No. 8

AVALANCHE ATLAS OF THE MILFORD TRACK
AND ASSESSMENT OF THE HAZARD TO WALKERS

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INTRODUCTION

The Milford Track is New Zealand's most famous walking track. It is a trail between the head of Lake Te Anau and Milford Sound in New Zealand's Fiordland National Park which occupies more than a million hectares in the south west of the South Island. The Track, sometimes described as "the finest walk in the world", is 55 km long, and is virtually the same as the overland route discovered by Quintin Mackinnon in 1888. It follows the Clinton River to its source at Lake Mintaro, crosses the Mackinnon Pass (1154 m) and descends into the Arthur Valley, skirting such features as Sutherland Falls and Lake Ada, to terminate at Sandfly Point at the head of Milford Sound (Fig. 1).

The Milford Track is used by large numbers of trampers and tourists from November to March, and by a few people in winter. The three day walk traverses terrain similar to the Te Anau to Milford highway, where a series of large and dangerous avalanches create a "moderately high" hazard to present day road traffic users (Fitzharris and Owens 1980). In recent years avalanches have killed one person on the Milford Track, severely damaged Pompolona Hut in conjunction with flood, and destroyed several small bridges.

Other popular walking tracks in New Zealand, such as the Routeburn, Copland and Ball Hut, are also subject to avalanches so there is a need to develop a methodology that objectively describes and compares their hazard. This report attempts to do this for New Zealand's most famous walking route, the Milford Track, by modifying the procedures used to assess the avalanche hazard along the Milford Road.

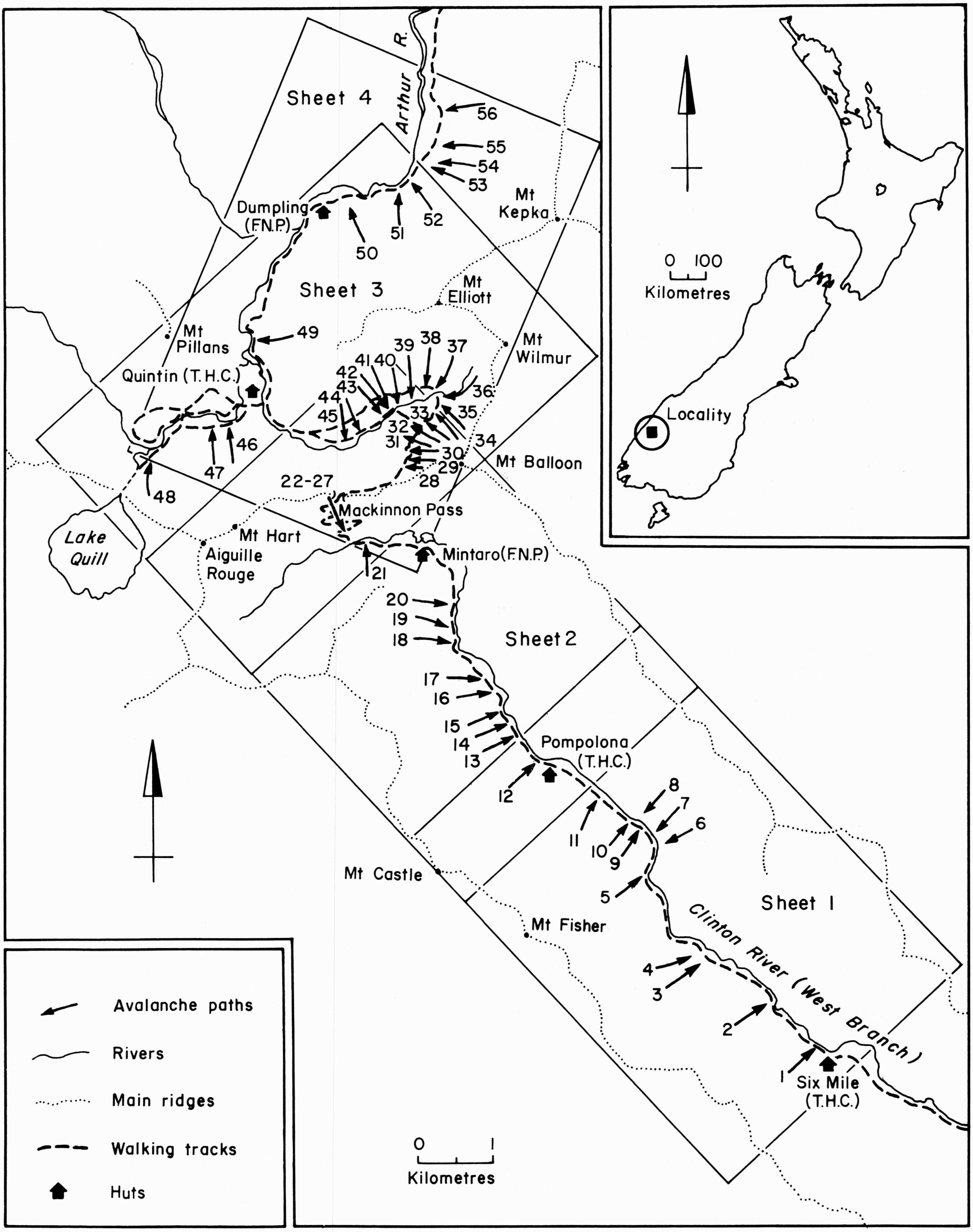


Fig. 1. Location of the Milford Track and of the avalanche paths

PURPOSE OF ATLAS

The objectives of this atlas are to:

1. Map and describe the avalanche paths which cross or come near to the Milford Track.
2. Assess the danger to the walking public by calculating a modified form of an internationally used hazard index.
3. Make recommendations for future management of the Milford Track avalanche hazard.

The atlas can be used as a management tool for the operation of the track, and as a zoning plan for safe siting of buildings and other structures. It should also be consulted by Tourist Hotel Corporation (THC) guides, Fiordland National Park (FNP) staff, those responsible for public safety on the Milford Track, and by other regular users who wish to minimise the risk to their lives from the avalanche hazard. Avalanches are common phenomena within the Park and we also hope this atlas will lead to an increased understanding of a spectacular aspect of its natural history.

AVALANCHES IN FIORDLAND

The Milford Track traverses the glacially eroded heart of Fiordland. The sides of deep U-shaped valleys have been spectacularly over-steepened by the ice, but extensive, occasionally permanent snowfields remain perched above. Fig. 2 illustrates the formation of this terrain caused by retreat of the glaciers. When the snow cover becomes weak or overloaded, large masses of snow begin to slide, eventually plunging down the mountain walls into the valleys below. Fig. 3 shows the vertical profiles of some typical avalanche paths along the Milford Track. As the snow moves down the convex avalanche paths, the valley sides become progressively steeper. The snow can therefore sometimes free fall, (Fig. 4), landing with explosive impact that produces such devastating effect that trees are destroyed, pressure ridges and depressions are formed in the soil and gravel at the point of impact, and rivers are dammed and diverted.

Avalanching occurs on a grand scale in Fiordland because the oversteepened terrain is combined with very heavy precipitation that exceeds 8000 mm per year. Smith (1947), who first described avalanches of the region in some detail, reported that in the nearby Upper Hollyford Valley, the number of avalanches often exceeded 60 per km per year. He described two main types of avalanches in Fiordland:

(a) Wet snow avalanches which occur generally during a period of thaw, and are most common from July to November. They tend to be noisy and slide down the mountain with little powder snow but with much rubble.

(b) Dry snow avalanches which occur more irregularly from May to November. These avalanches are initiated during snow storms, generate much powder snow and often descend silently. In addition they are accompanied by a destructive air blast on a narrow front in a direction sometimes inclined to the path of the main avalanche fall. Starting zone conditions which could initiate avalanches of this type are outlined in Fig. 5.

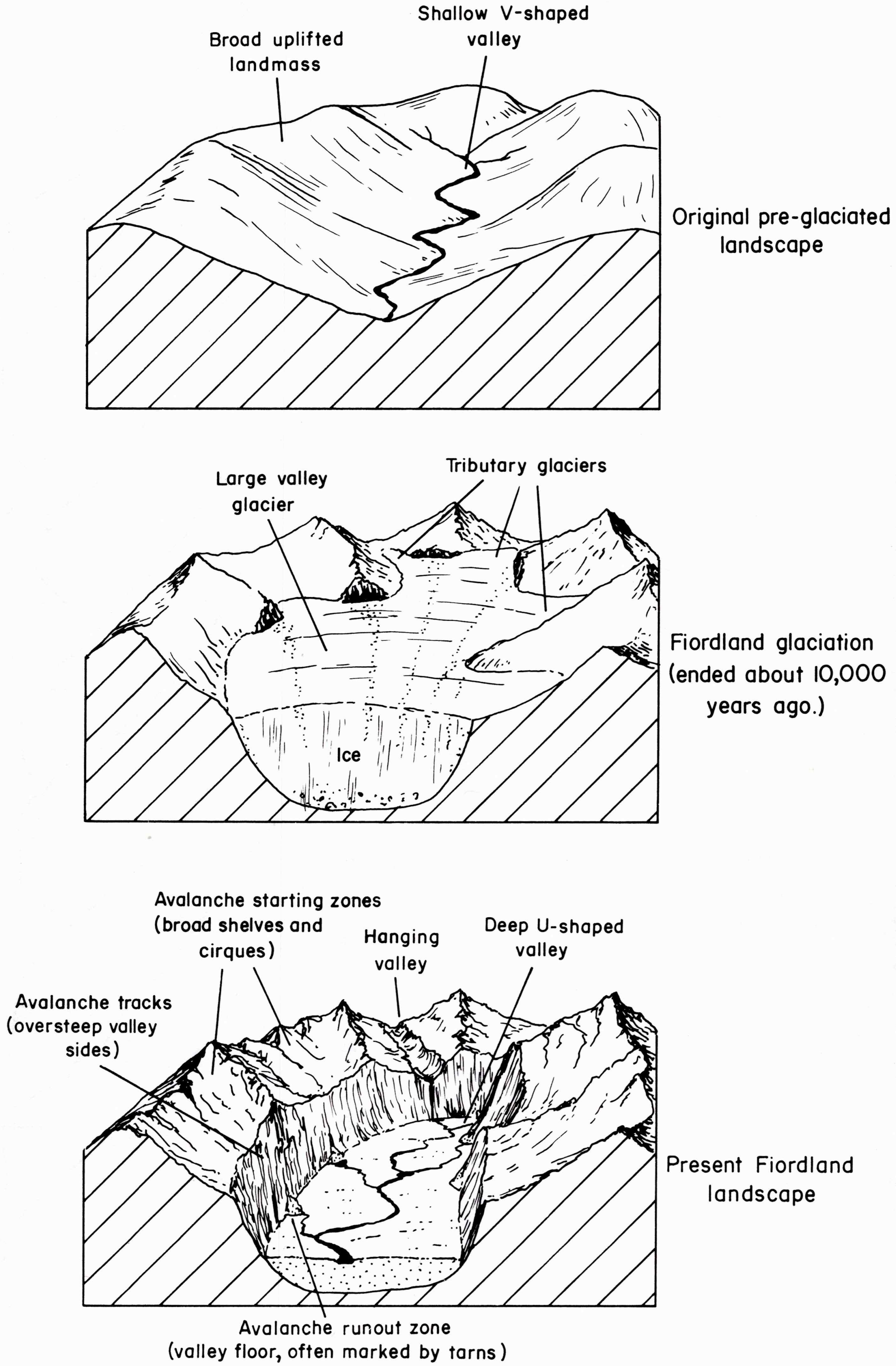
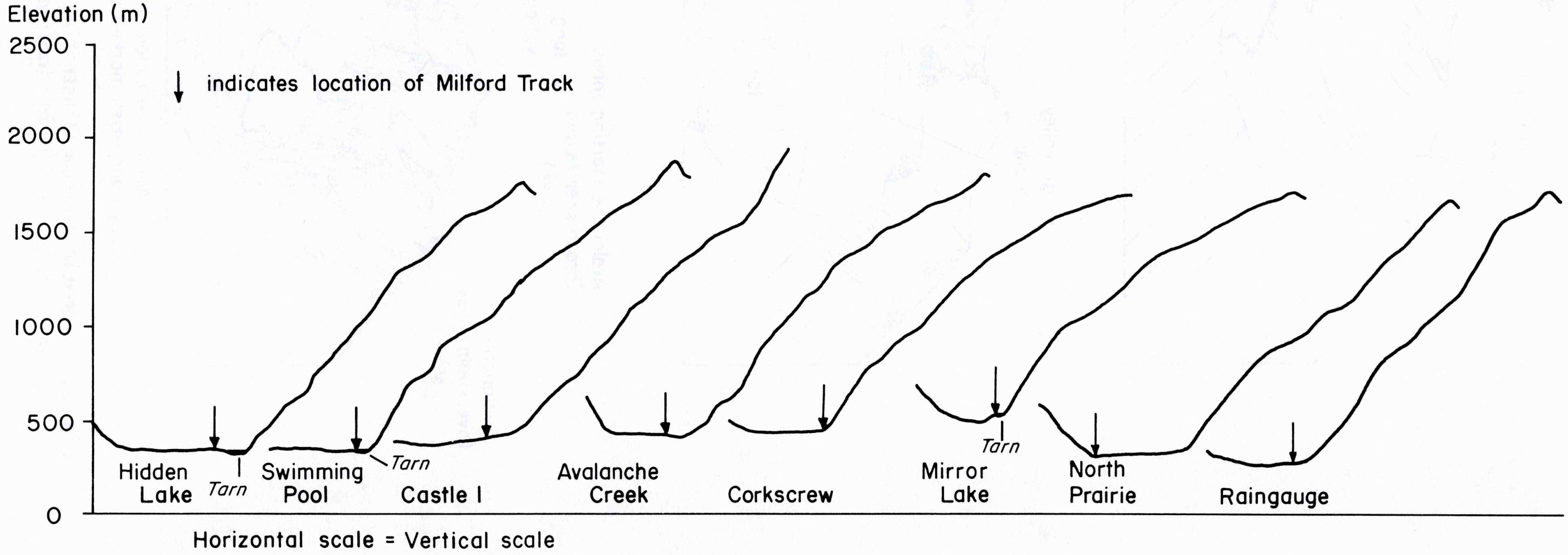

Shallow V-shaped valley
Broad uplifted landmass
Original pre-glaciated landscape
Tributary glaciers
Large valley glacier
Fiordland glaciation (ended about 10,000 years ago.)
Ice
Avalanche starting zones (broad shelves and cirques)
Hanging valley
Deep U-shaped valley
Avalanche tracks (oversteep valley sides)
Present Fiordland landscape
Avalanche runout zone (valley floor, often marked by tarns)

Fig. 2. Schematic diagram illustrating how glaciation has led to the formation of U-shaped valleys in Fiordland, with steep valley sides.

Fig. 3. Vertical profiles of some avalanche paths along the Milford Track.



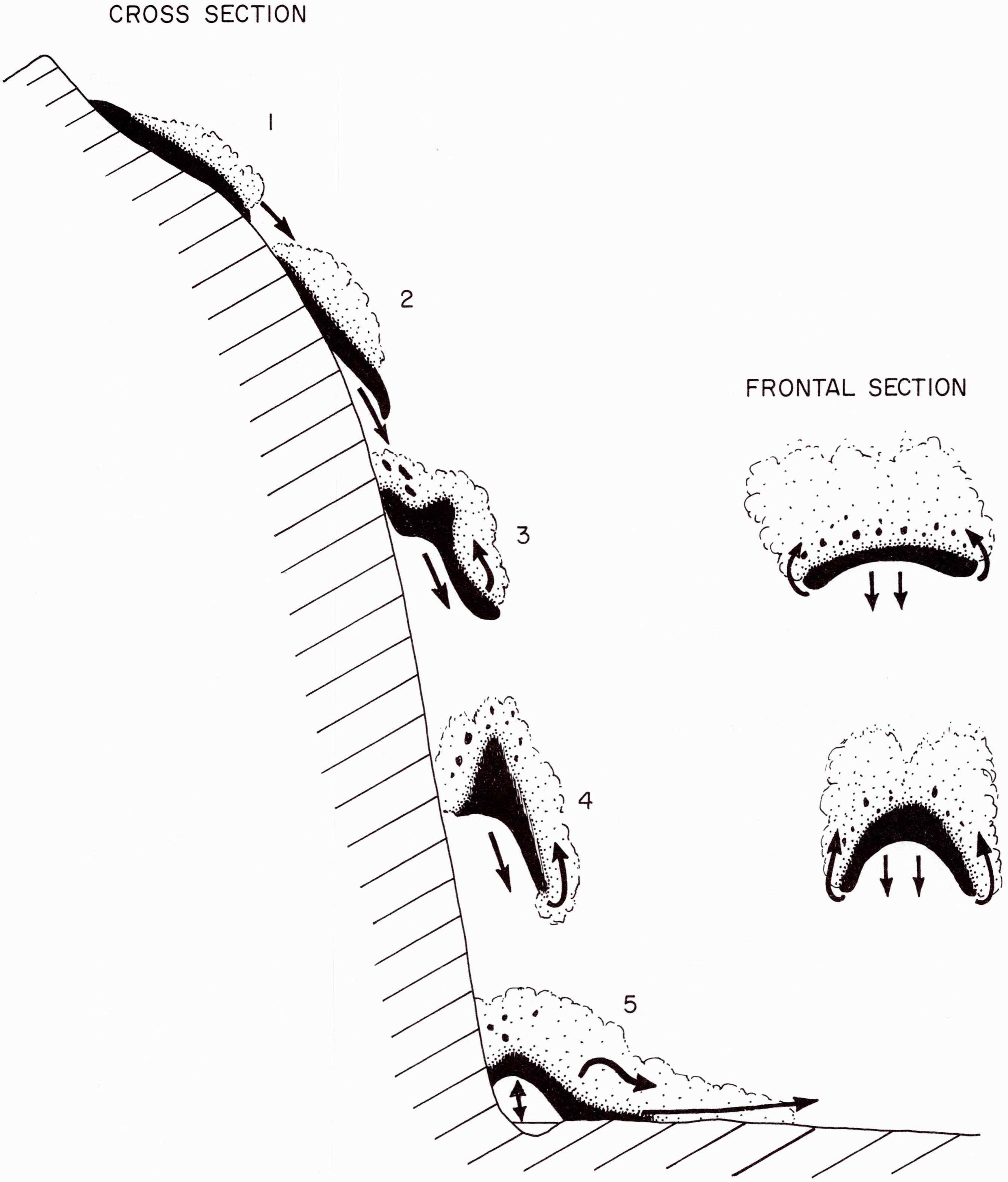


Fig. 4. Sequence showing the probable fall of a large Fiordland avalanche (modified from Smith, 1947).

THE TERRAIN OF AVALANCHE PATHS ALONG THE MILFORD TRACK

Avalanche paths are commonly divided into three zones as shown in Fig. 6. In the Milford area, terrain in these zones is often quite different to many other avalanche areas of the world. "The terrain's" characteristics are described here in general terms, while more detailed information on individual paths is supplied in the Appendix.

Avalanche Starting Zones:

These are areas in which snow accumulates, and are usually located high on the mountain in cirques or on shelves. For large avalanches to occur, slopes in the starting zone must be steep enough so the snow will eventually slide off, but gentle enough to allow considerable depths of snow to accumulate before failure. Starting zone angles of 30^{o}-45^{o} predominate in avalanche areas throughout the world, and this is also the case along the Milford Track with angles averaging 41^{o}. However, the wide range of starting zone slopes from 25^{o}-69^{o} is unusual though the very steep ones produce relatively small avalanches. Because of the imprint of past glaciation on the landscape, there is often a distinct slope change at the upper elevation of the former glacier surface, usually about 1300 to 1500m. Below this level, there are few starting zones because slopes are too steep to accumulate significant quantities of snow.

The terrain within starting zones is also important for avalanche initiation. Along the Milford Track starting zone terrain is evenly distributed between steep slopes, broken or shelved areas, and cirques or bowls.

Very rough and broken terrain requires a considerable depth of snow before a suitable sliding surface is available. Therefore, observations of the extent to which surface irregularities are covered by snow can sometimes be used as a guide to the likelihood of avalanches. On smoother terrain, such as scree, snow grass, or permanent snow and ice, less new snow is required for avalanche release. Thus, those avalanche paths with permanent snow and ice, such as Pompolona and Jervois, are very large and dangerous, and frequently produce large avalanches. However, only about 10% of the starting zones along the Milford Track are of this type - fewer than along the Milford Road where almost half are in permanent snow and ice.

Another factor affecting avalanche occurrence is the aspect of the starting zone. The most favourable aspects are in the lee of prevailing storm winds, so that in Fiordland, where winds from north-west to south-west are commonly associated with snowfall, those slopes facing south-east to north-east receive the heaviest loads of wind-blown snow (Fig. 5). However, the bowl-shaped starting zones can be loaded from a range of directions, while gully-shaped starting zones are often loaded by winds blowing across them. Thus a gully running in a northerly direction may be "cross-loaded" by either west or east winds.

Aspect of starting zones on the Milford Track is largely controlled by the orientation of the major valley systems. Most of the valleys run approximately north-west to south-east. Consequently, paths with north-easterly aspects predominate, most notably along the true right of the Clinton Canyon, although other aspects also occur. The north and north-west aspects can be particularly dangerous on clear days in spring and early summer because solar radiation may weaken the snowpack and lead to avalanche release. Avalanches of this type

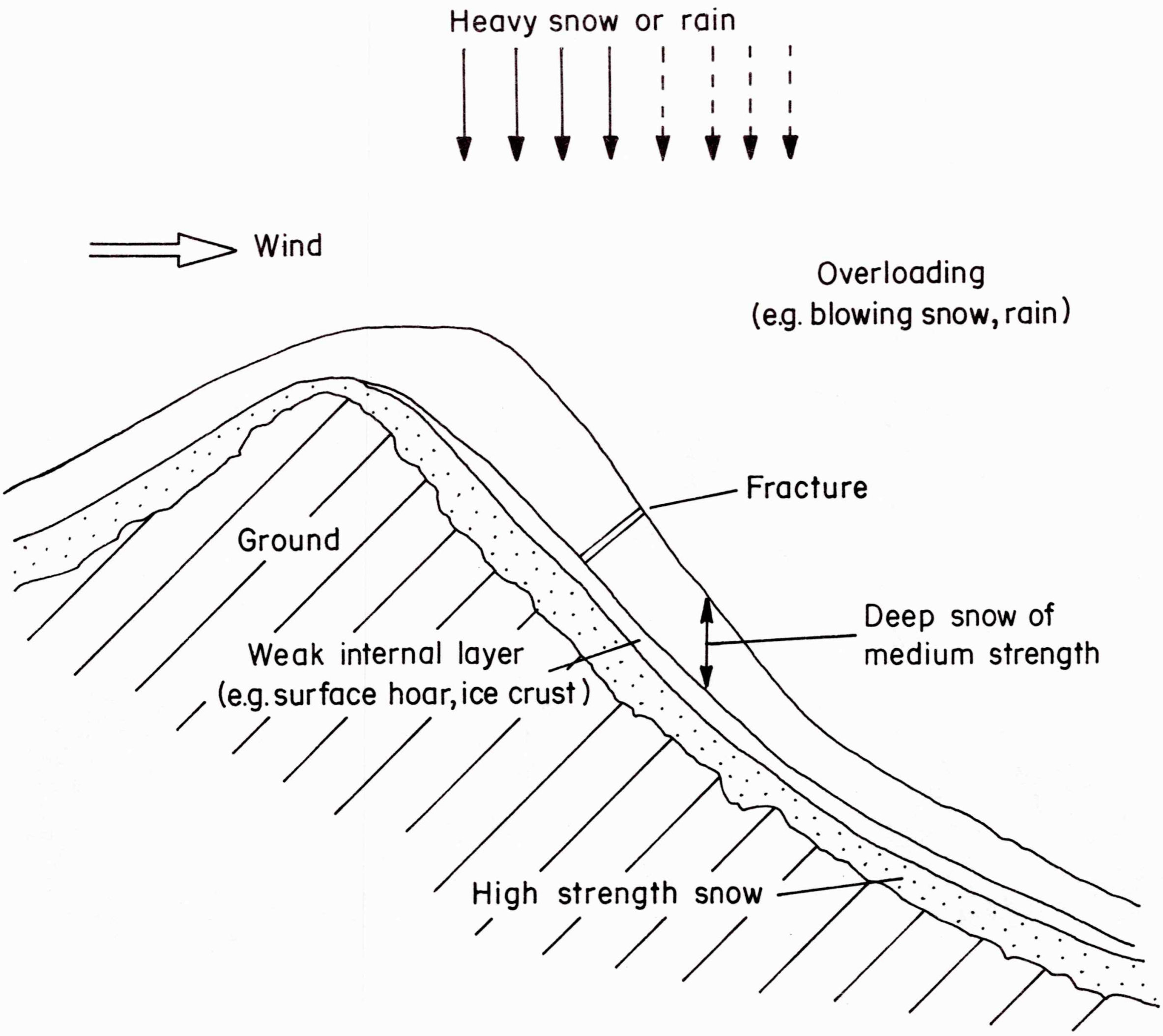


Fig. 5. Profile of the starting zone of a Fiordland avalanche path, illustrating the factors which lead to large avalanches.

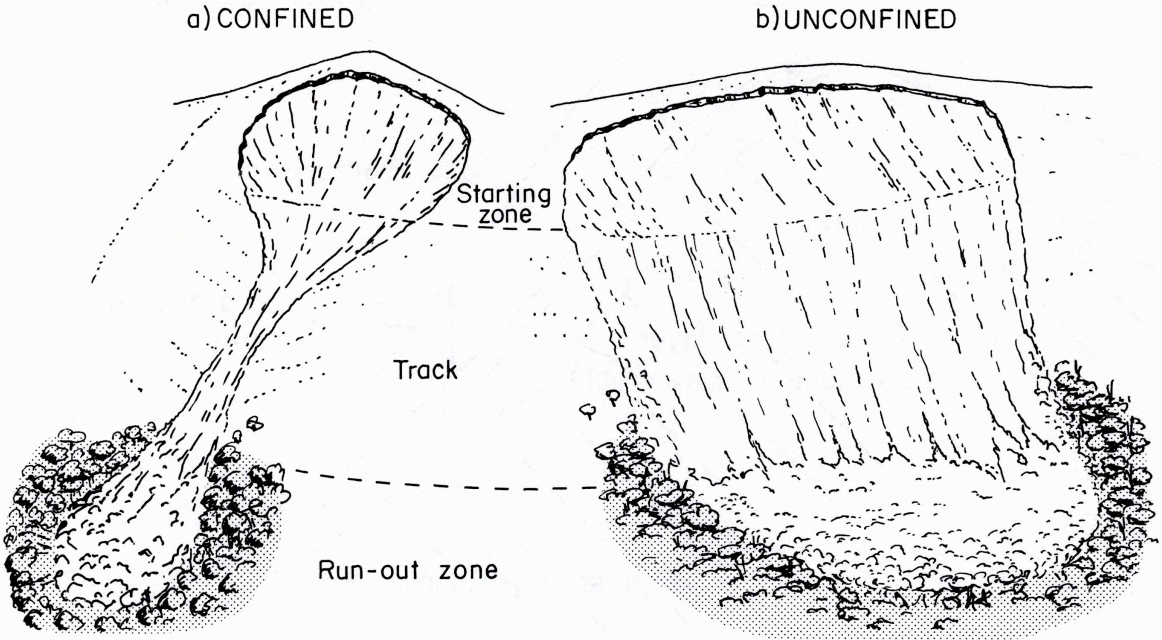


Fig. 6. **Morphology of avalanche paths showing starting zone, track and runout zone.**

sometimes cross the Milford Track along the flanks of Mt. Balloon.

The size of the starting zone is a measure of the potential magnitude of an avalanche in a given path. A few above the Milford Track have areas up to 1 km^2, which is large compared with avalanche terrain elsewhere. For example in the Mt. Cook region, avalanches have starting zones only up to approximately 0.5 km^2, while Bovis and Mears (1976) report a range of 0.02 to 0.6 km^2 for 67 avalanches in Colorado. However, while three of the starting zones along the Milford Track exceed 0.5 km^2 in area, over 70 are less than 0.2 km^2.

Avalanche Tracks:

These are the areas below the starting zone through which the avalanche accelerates as it passes into the valley below. In most areas of the world, avalanche tracks are concave, with slopes that average 20^o to 30^o. In the Milford area, however, the glacial terrain has produced tracks with very steep slopes, averaging 47^o, and they tend to be convex (Fig. 3).

The coarsely crystalline granites and gneisses of Fiordland resist erosion, and so have preserved the glacial-shaped valleys, the sides of which now provide the steep avalanche tracks. This resistance to erosion of Fiordland rocks also means that the tracks along the Milford Track are almost always unconfined. Only 20% have confined sections and these are small and form but part of the track. This feature is in marked contrast to avalanche regions where the rocks are more erodible. There, avalanches are usually confined, running in small gorges or guts throughout most of the track.

Avalanche Run-out Zones:

The resistant rocks of the Milford area also influence the character of the run-out zones, the part of the path where the avalanche slows and eventually stops. In many mountainous areas elsewhere, avalanches run out onto extensive fan-shaped deposits built up by avalanching deposits and by other processes such as debris flows and stream deposition. The angles of slope on these fans are commonly in the range 5^o to 15^o. However, few of these fans are to be found along the Milford Track. The large fans that do occur, such as just before Six Mile Hut and at Pompolona, have resulted from catastrophic landslide events. Instead, a much more common landform are small rockfall and avalanche debris fans, usually with surface angles of about 20^o, that form at the junction of steep valley sides and valley bottoms. These are particularly prevalent in the section from Pompolona to Mintaro (Fig. 7) and along the "Racecourse" from Coby to Phar Lap (Fig. 8). Downstream from Pompolona, the valley is broader and avalanches run out onto river flats with slopes of 5^o and less. In some cases, for example at Hidden Lake and Swimming Pool (Fig. 9 & 10) tarns have been formed by the explosive impact of large avalanches plunging into the valley floor, after free falling from the cliffs above. There are also clear signs of vegetation damage, of pressure ridges, and of explosive ejecta at these locations. A few avalanches end on much steeper slopes of around 30 ^{o}. Such paths are generally small, end in gullies of mature bush, and mainly occur on the Track about the McKinnon Pass.

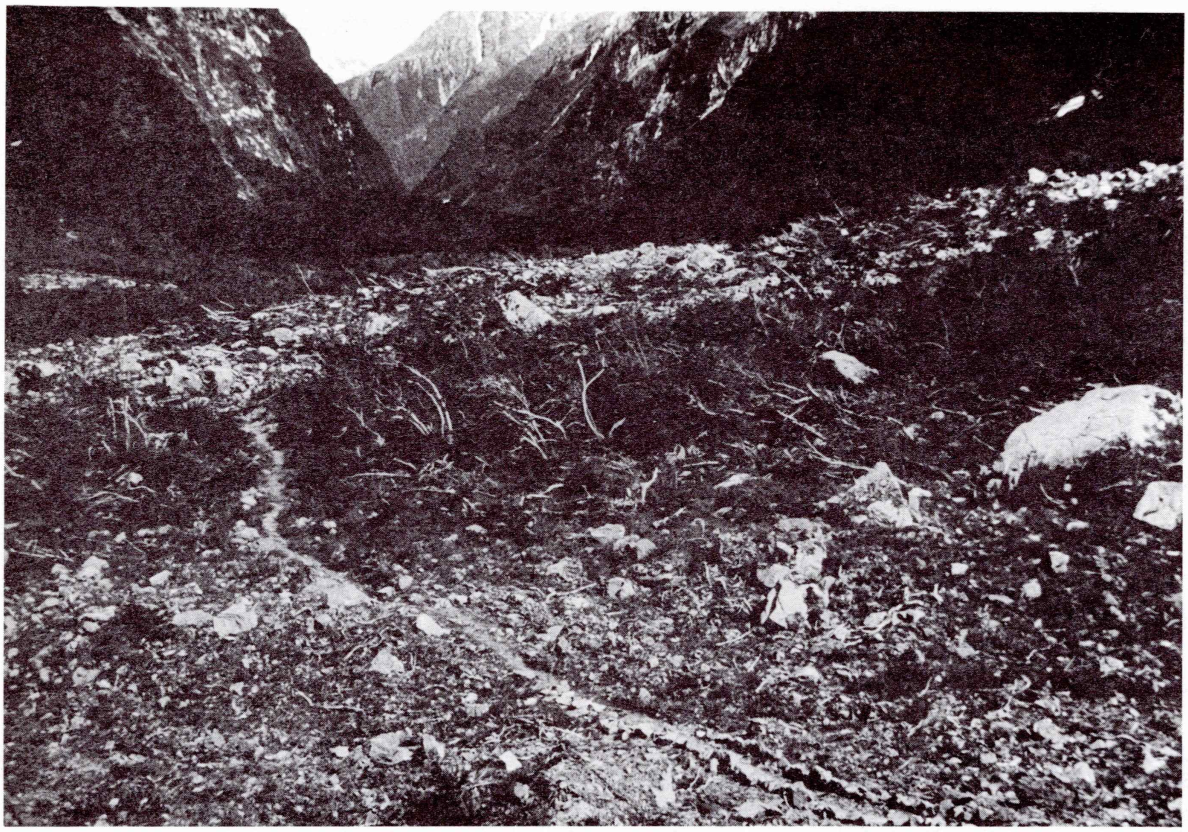


Fig. 7.: View of the west side of the Clinton Canyon between Pomplona and Mintaro illustrating small rock and debris fans in the runout zone of avalanche paths.

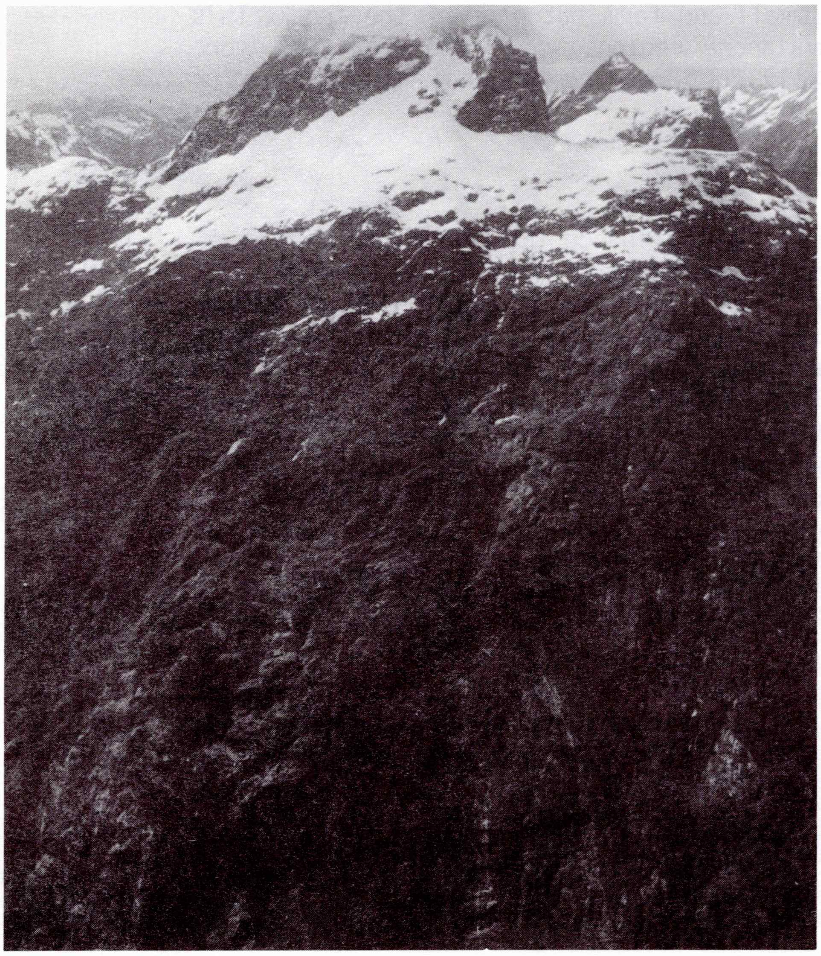


Fig. 8. Vegetated fans below steep tracks in the Arthur Valley near Dumpling Hut.

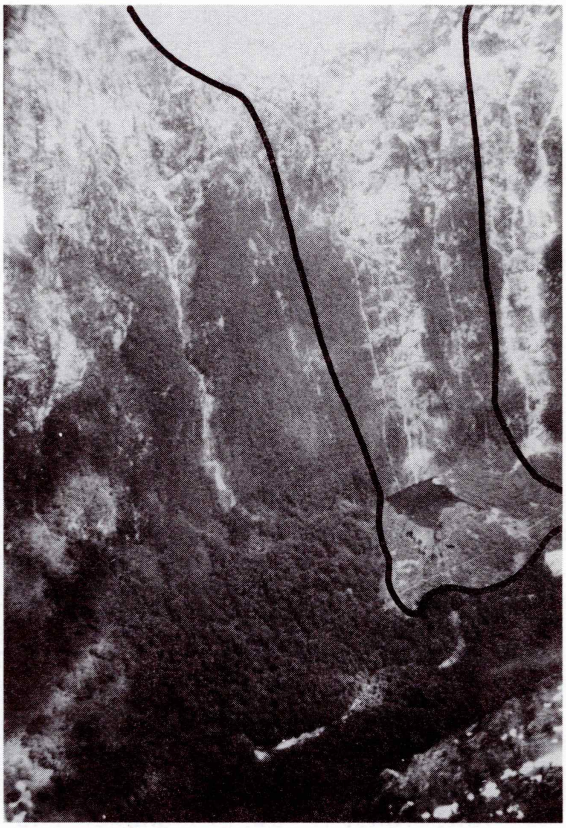


Fig. 9. Hidden Lake, an avalanche tarn formed by the explosive impact of avalanches plunging onto the valley floor.

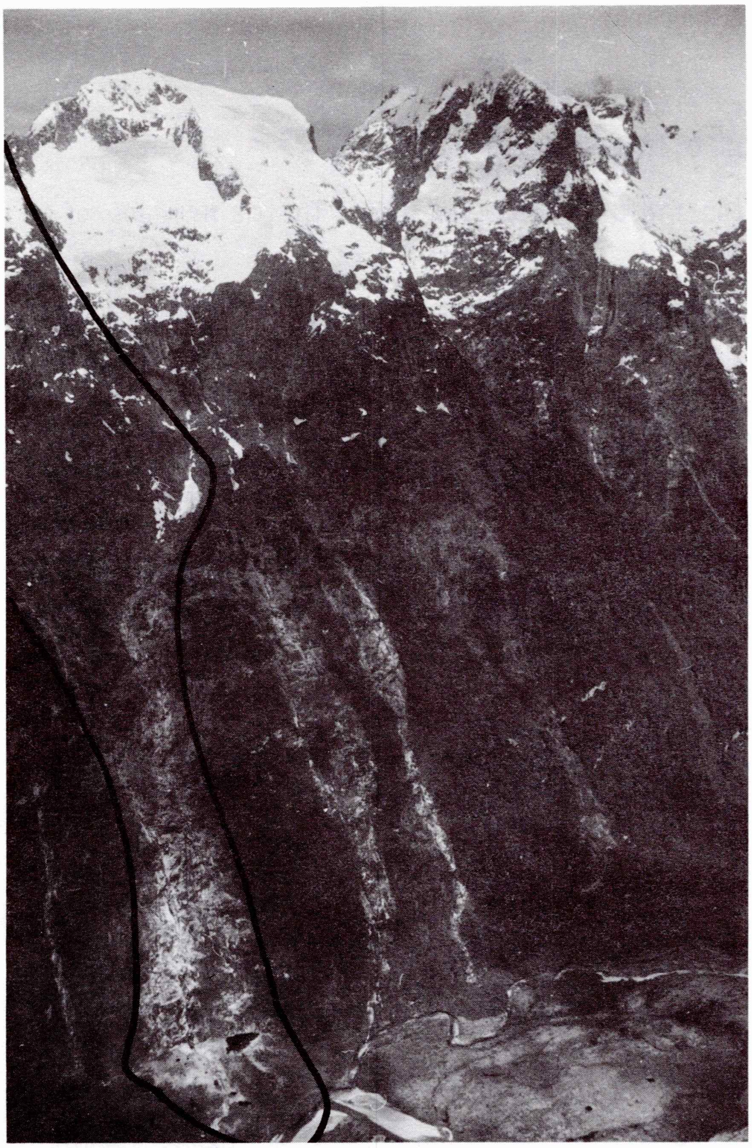


Fig. 10(a).
The Swimming Pool,
another avalanche
tarn

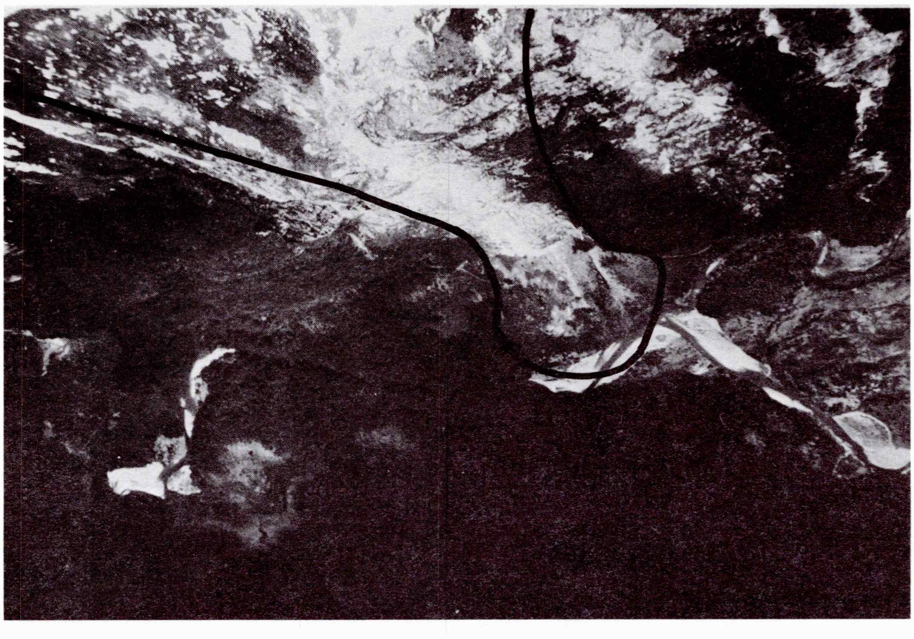


Fig. 10(b).
View of Swimming Pool,
looking down avalanche
path.

METHODS USED TO MAP AVALANCHES

Avalanche paths were mapped in the field in December 1982. The main means of identification were

(a) Observation of vegetation patterns on the ground and on aerial photographs (Scale 1:86,300).

(b) Examination of the terrain of the starting zones from the Track. Earlier observations were made from a light aircraft in the spring of 1982, and reinforced by close inspection from a helicopter in December 1982 and October 1983.

(c) Interviews with staff of Fiordland National Park, THC Milford Track staff and discussion with Zygmund Kepka, a climber with long experience on the Track, who accompanied us on our field work.

The avalanche paths were plotted on the best available maps (Scale 1:63,360 and 1:15,840). Where multiple, complicated runout zones intersected the Track, sketch maps of the detail and form of avalanche damage were made in the field and later transposed to the final map. All paths were photographed from the air, and each was given a commonly used, or local name.

The frequency of avalanches on each path was estimated by:

(a) observing the vegetation, (species and stage of regrowth);

(b) documenting the memories of those with long experience on the Track;

(c) examining the terrain of the starting and runout zones;

(d) applying our experience from the Milford Road (Fitzharris and Owens, 1980) where records of avalanche frequency are available back to 1936.

Because avalanches in the decade of the 1970s were less common than the long term average, and much less than the 1930-50 period, the memory of present day Track workers may be biased towards frequencies that are low. It is perhaps surprising that even though the Milford Track has been used for more than 90 years, most present staff have less than 10 years experience. Nevertheless we consider that all major paths to have produced avalanches onto the Track within the last 50 years are mapped within this atlas. Better estimates of frequency will depend on improved, more formal documentation of avalanche activity, together with careful analysis of climate records, particularly of precipitation and temperature, and also on detailed studies of forest regeneration based on dendrochronology.

LOCATION OF THE AVALANCHE PATHS

The avalanche paths which cross the Milford Track are located in Fig. 1, illustrated in detail in the Appendix, and described in Table 1. The first avalanche path **Six Mile**, is 200 m beyond Six Mile Shelter, the usual lunch stop for THC walkers during their first day on the Track. The last is **Phar Lap**, 5.5 km beyond Quintin, or 2.5 km beyond Dumpling Hut, so is passed by all walkers on the last morning of their tramp. In the intervening 23 km, 56 avalanche paths cross the Track, 27 on the south side of Mackinnon Pass and 29 on the north side. Thus walkers are crossing avalanche paths from the middle part of their first day until their last morning on the Track.

The heaviest concentration of avalanche paths, where 34 cross the Track, is between Pompolona and Quintin and is the section completed by THC walkers on their second day. Thirteen of these paths can be bypassed if the Emergency Track is used, while 3 of the paths are located along the side track to Sutherland Falls. Ten paths each cover 400 m or more of trail, although some (such as **Prairie**) are not very active during the Track season.

Because walkers move slowly on steeper grades, and because the Track sometimes zig-zags within an avalanche path, a better measure of the likely importance of each path is the time needed to cross it. Walkers tend to spend more than 10 minutes within the influence of **Hidden Lake 1, Zig-Zag 6, Balloon 1, Balloon 3** (if the emergency track is used), **Jervois** and **Elliot Walk** (which are both avoided by the emergency track), and **Raingauge** and **Arguille,** (both of which are on the Sutherland Falls trail). In all, a walker who uses the main track and visits the Sutherland Falls is likely to spend almost 4 hours within avalanche paths, but can reduce this by half an hour if the emergency track option is used.

During the winter, avalanches will cross the Track at least once a year at **Hidden Lake** (near the tarn itself), **Pompolona, Castle 1, Waterfall, Corkscrew** and at 21 of the 22 paths between **Zig Zag** and **Elliot Ridge.** During the walking season it is expected that **Pompolona, Castle 1,** and **Corkscrew** will influence the Track on average about once each year. **Avalanche Creek, Waterfall, Nicolas,** most of the **Zig Zags, Balloon 5,** and **Pepper** can be expected to deposit avalanche snow on the Track at least twice in a decade during the walking season.

Most of the avalanches are very large when they run big enough to reach the Track. Several such as those at **Hidden Lake, Swimming Pool, Corkscrew, Balloon, Jervois** and **Elliot Wall** can plunge directly onto areas occupied by walkers with very high impact forces. Although such events are relatively common in winter, they will be rare during the Track season, unless the snowpack is heavy, or is late in thawing, or a large snowstorm occurs. Other avalanche paths such as the **Zig-Zags** and **Cols** are small, but are regarded as dangerous because walkers crossing the Pass traverse the starting zone and can trigger an avalanche which sweeps them or the rest of the party downslope. Other relatively small paths, such as those off Mt Balloon, will avalanche soon after a heavy, late spring, or summer snowstorm, because their terrain is steep and subject to rapid warming from solar radiation.

Fifteen of the 56 paths that cross the Milford Track have only a remote chance of doing so during the Track season with frequencies of but once in 50 to 100+ years.

THE BEGINNING OF THE MILFORD TRACK

The story of the Milford Track began in the late 1870s when Donald Sutherland became the first settler at Milford Sound. On 10 November 1880, he and John Mackay, while blazing a trail up the Arthur Valley, discovered the Sutherland Falls, which were then thought to be the highest in the world. Although this claim was rejected eight years later when their height was determined as 580 m

Table 1. List of the avalanche paths which cross the Milford Track.

NO. OF PATH	AVALANCHE PATH	TIME OF TRAVERSE (minutes)	LENGTH OF TRACK AFFECTED (m)	$1/f_w$ (years)	$1/f_s$ (years)	P_w X 10^{-3}	P_s X 10^{-4}	GENERAL LOCATION
1	SIX MILE	2	200	30	50	0.002	0.018	
2	NOTCH	1	50	30	50	0.001	0.009	
3	HIDDEN LAKE 1	8	400	30	100	0.009	0.036	
3		15*	100	0.3	20	1.067	0.341	
4	HIDDEN LAKE 2	3	150	30	100	0.003	0.014	
5	SWIMMING POOL	5	200	20	50	0.008	0.045	
6	JUNCTION			30	-			
7	PRAIRIE	6	600	30	-	0.007	-	
8	NORTH PRAIRIE			30	-			
9	FISHER 1	1	50	20	20	0.002	0.023	
10	FISHER 2	0.5	25	50	50	0.001	0.005	Clinton Valley
11	FISHER 3	1	100	30	30	0.001	0.015	
12	POMPOLONA	3	100	30	50	0.003	0.027	
12		3*	50	0.2	1	0.500	1.364	
13	CASTLE 1	6	600	50	100	0.004	0.027	
13		0.5*	25	0.2	1	0.083	0.227	
14	CASTLE 2	3	300	50	100	0.002	0.014	
15	CASTLE 3	7	700	20	50	0.012	0.064	
16	AVALANCHE CREEK	3	250	0.5	3	0.200	0.454	
17	WATERFALL	4	350	10	20	0.007	0.182	
17		2*	200	0.5	3	0.133	0.303	
18	CORKSCREW	4	400	5	2	0.027	0.909	
18		2*	200	0.2	0.5	0.333	1.818	
19	NICHOLAS	4	350	1	5	0.133	0.364	
20	MIRROR	0.5	25	5	30	0.003	0.008	
21	MINTARO	0.5	25	20	50	0.001	0.005	
22	ZIG-ZAG 1	0.5	20	20	50	0.001	0.005	
22		6	300	0.5	10	0.400	0.273	
23	ZIG-ZAG 2	2		20	50	0.003	0.018	
23		2	20	0.3	5	0.222	0.182	
24	ZIG-ZAG 3	1	50	0.3	5	0.111	0.091	
25	ZIG-ZAG 4	2	100	0.3	5	0.222	0.182	
26	ZIG-ZAG 5	2	100	0.3	4	0.222	0.227	McKinnon Pass Area
27	ZIG-ZAG 6	10	200	0.3	3	1.111	1.515	
28	COL 1	0.5	20	0.05	10	0.333	0.023	
29	COL 2	1	30	0.05	10	0.666	0.045	
30	BALLOON 1	15	150	0.05	10	10.000	0.682	
31	BALLOON 2	5	50	0.05	10	3.333	0.227	

NO. OF PATH	AVALANCHE PATH	TIME OF TRAVERSE (minutes)	LENGTH OF TRACK AFFECTED (m)	$1/f_w$ (years)	$1/f_s$ (years)	P_w X 10^{-3}	P_s X 10^{-4}	GENERAL LOCATION
32	BALLOON 3	1	30	0.05	10	0.666	0.045	Not included in Emergency Track
32		15~	30	0.05	10	10.000~	0.682~	
33	BALLOON 4	0.5	30	0.05	15	0.333	0.015	
34	BALLOON 5	2	100	0.05	5	1.333	0.182	
35	FINAL LEAP	4	200	0.10	20	1.333	0.091	
36	CRESCENT	3	200	10	50	0.010	0.027	
37 38	JERVOIS) ELLIOT WALL)	15	1500	0.3	10	16.667	0.682	
39	ROARING CREEK	5	500	0.5	10	0.333	0.227	
40 41	ELLIOT RIDGE 1) ELLIOT RIDGE 2)	6	600	0.3	10	0.667	0.273	
42 43	ELLIOT TRACK 1) ELLIOT TRACK 2)	2	100	0.3	30	0.222	0.030	
44	ELLIOT TRACK 3	0.5	30	1	30	0.017	0.008	
45	ELLIOT TRACK 4	0.5	30	10	30	0.002	0.008	
46	RAINGAUGE	15	750	20	30	0.025	0.227	Sutherland Falls Track
47	HART	3	150	30	50	0.003	0.045	
48	AIGUILLE	12=	350	25	50	0.016	0.109	
49	GENTLE ANNIE	0.5	20	50	100	0.001	0.002	Arthur Valley
50	COBY	2	200	50	-	0.001	-	
51	BOSSY	4	350	20	-	0.007	-	
52	PEPPER	4	350	1	5	0.133	0.364	
53	BALMARINO	2	200	20	-	0.003	-	
54	YOUNG QUINN	3	250	20	-	0.005	-	
55	CARDIGAN BAY	3	300	10	-	0.010	-	
56	PHAR LAP	2	200	30	-	0.002	-	
	ALL PATHS	222 198~				40.055 29.088~	11.807 10.946~	
	TOTAL HAZARD INDEX					6.0 4.4~	8.3 7.7~	

This table gives detailed scores for the Hazard Index for winter, (P_w) and track season (P_s). Values are given per person for each path, but the totals are for 7000 walkers in the Track season, and 150 walkers during f_w and f_s are the frequencies of avalanches in the winter and track season, respectively. A value, of say, 30 for $1/f_w$ means that an avalanche can be expected once in 30 winters.

~ indicates value if Emergency Track used

* allowance made for more frequent, but smaller avalanches,
or for extra time spent sightseeing, as at Hidden Lake and Sutherland Falls

by C.W. Adams, the Chief Surveyor for Otago, the Falls continued to create much interest. During the 1880s ships delivered tourists to Milford Sound, who would then walk up the Arthur Valley to view the Falls.

Quintin Mackinnon and his companion Ernest Mitchell pioneered the Milford Track in September 1888 when they struggled up the Clinton Valley, and showed that by crossing the Mackinnon Pass, a link could be made with Lake Te Anau, the Sutherland Falls, Arthur Valley and Milford Sound. Almost immediately the Track became a tourist attraction, and by the 1890s was being promoted and amenities built. The guide's fee was twelve shillings per day per person, with those engaging guides having the preference for huts (Reed 1965).

The Milford Track first became known as the "Finest Walk in the World" in 1908 when it was described in **The Spectator**, London. Thereafter it has continued to be developed and used by tourists up to the present time.

Most early accounts of conditions on the Track refer to avalanches. Reed (1965, p.38) describes one such report from the spring of 1888:

> 'While Mackinnon and Mitchell were fighting their way through the Clinton Canyon, and a couple of days before they traversed the pass, a small party had left Milford Sound to search for a pass on that side. Before leaving the Sound they experienced a deafening thunderstorm. 'The whole country', said Thomas Mackenzie, a member of the party, 'appeared to shake with each peal'. This was followed by the fall of a colossal avalanche between Lake Ada and the Sutherland Falls, sweeping the mountainside to the base rock over an area of half a mile, blocking the river, and backing it up. Great flooding followed when the river broke through, during which the photographers with the party (Muir and Moodie) had their tent carried away.'

Various files related to National Parks and Reserves that are held at the National Archives in Wellington also refer to avalanches along the Milford Track. In 1938 one letter briefly mentioned the reluctance to maintain huts at high standard because of avalanche danger. Reports from track foremen mentioned five avalanches before Mintaro in 1941, the trouble and extra work caused by avalanches and claimed compensation for luggage lost in an avalanche.

Avalanches began early in 1944, with the Track impassable due to fallen trees in late May, while 1946 was described as "the worst year experienced" with "very recent earth, rock and tree avalanches of gigantic proportions." Conditions were so bad, that a report on 16 December 1946 stressed the continuing avalanche danger due to unstable upper snowfields. It is also known that a similar late snowpack threatened the Track in 1968.

ORGANISATION OF WALKERS ON THE MILFORD TRACK

All modern day walkers of the Track start their journey at Te Anau Downs, midway up Lake Te Anau, and travel by boat to Glade House at its head. The traffic on the Track is one way, that is, north over Mackinnon Pass and thence to Milford Sound, where a further boat trip takes walkers to Milford itself. At Quintin Hut, a short diversion allows walkers to visit the base of Sutherland Falls. Numerous other side trails exist about Quintin, such as the Anderson Track, but their use is now discouraged and they are little maintained. However, in order to avoid the danger from avalanches that fall off Jervois Glacier, the Emergency Track is more frequently used. This detours on the northern side of Mackinnon Pass and descends more steeply into the bush, largely following a lower elevation route before rejoining the main track before Quintin Hut (see Fig. 11).

Walkers who travel independently stay in huts administered by Fiordland National Park, and are termed "freedom walkers". They pay relatively small hut fees but must carry all food, clothing and sleeping requirements. They stay the first night at Clinton Forks (or Four Mile) Hut, the second at Mintaro Hut, and the third night at Dumpling Hut. Unless the weather is extreme they are expected to stay in each hut only one night, and to proceed further on the Track the next day. Each hut has a Ranger or Park Assistant who advises on weather and Track conditions.

A larger number of people walk the Track under the auspices of the Tourist Hotel Corporation. They pay substantially more than the freedom walkers, but are provided with all food and bedding, and stay in superior accommodation at Glade House, Pompolona and Quintin on successive nights. Each hut has staff who advise and cook for the walkers. THC walkers are also expected to move to the next hut at the beginning of each day, unless prevented by weather, flood or avalanche from advancing further. In the early part of the season, when the avalanche danger is more likely to be critical, THC parties use the Track on alternative days, so that any such delay can be accommodated within the management system. Each party of THC walkers is accompanied by at least one guide.

The THC operates the Milford Track as part of a larger integrated operation that links with their hotels at Te Anau and Milford, and elsewhere in New Zealand. The Track is promoted internationally, so that many of the THC walkers are overseas tourists. THC estimates that the Track earns in excess of one million dollars per year, with a flow-on income to other parts of their operation maybe two times greater.

NUMBER USING THE MILFORD TRACK

It is thought that about 200 people per year walked the Track per year in the 1890s. By the 1930s the numbers probably rose to 1000 or so per year, but early records are difficult to find. A large increase in numbers occurred from the late 1960s when freedom walkers were first allowed. In the 1967-68 season there were 2681 THC walkers, but less than half that the next year when a very deep snowpack with many avalanches delayed the opening of the Track. In the years 1970-72, about 2100 THC walkers were guided annually, and by 1983 the total numbers on the Track had risen to 7000 per year, made up of 4000 THC walkers and 3000 freedom walkers. The THC plans further expansion of their numbers both by enlarging the sleeping capacity of their huts, and by extending the season.

In recent years the walking season has begun in early November and extended until autumn. This avoids the main avalanche period which in Fiordland normally extends from May to November, with peak activity in August and September. However, during cool, wet springs such as occurred in 1982, or after a very heavy snowfall winter such as in 1968, the snowpack is maintained so that avalanches can still endanger the track as late as January. Some avalanches will run across the Track after any heavy snowfalls, even those which occasionally occur in summer.

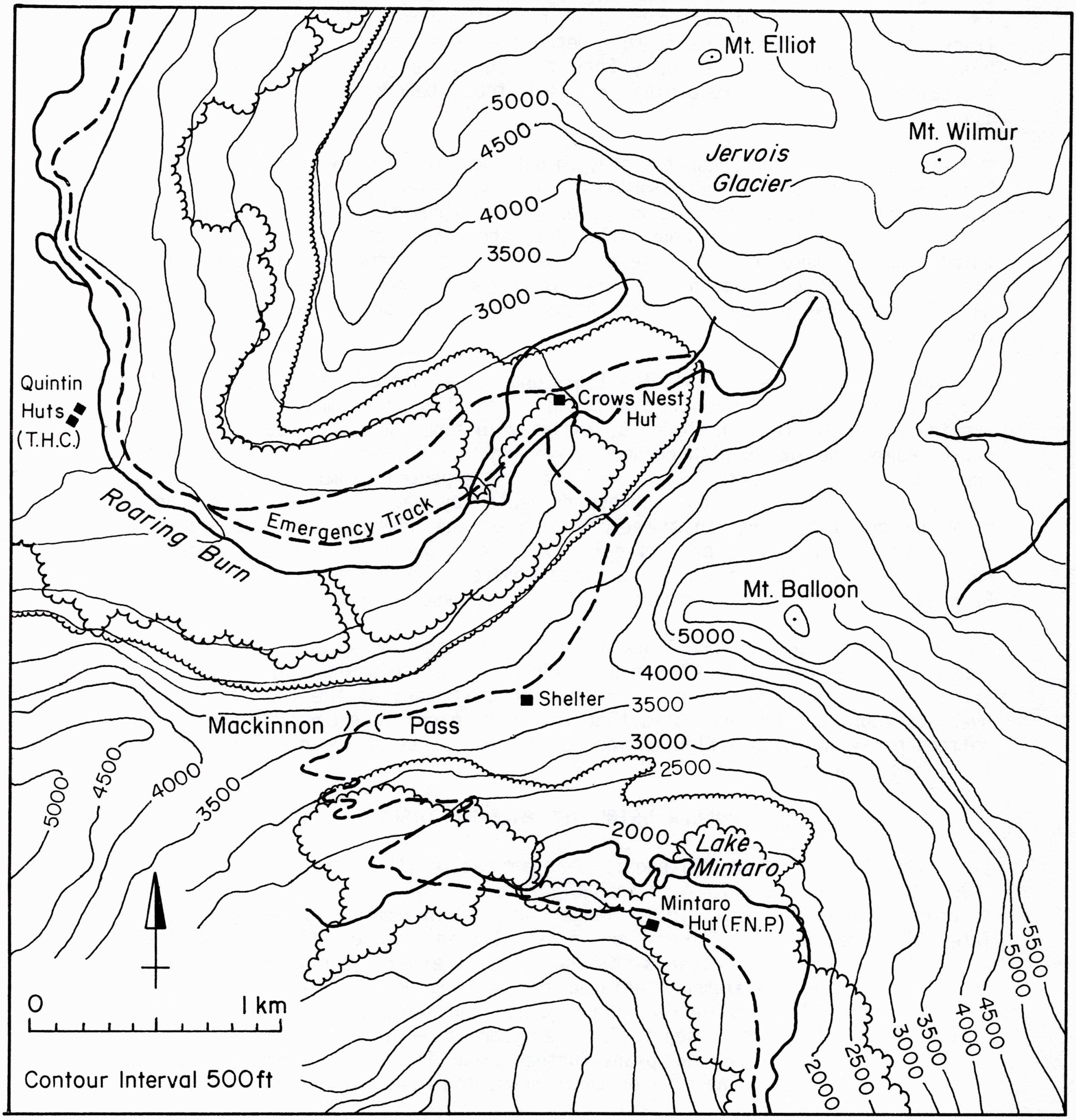


Fig. 11. Detail of the Milford Track from Mintaro to Quintin showing the huts, Mackinnon Pass, & the Emergency Track.

METHODS USED TO ASSESS THE AVALANCHE HAZARD

Definition

A Hazard Index, a numerical expression of the danger to traffic, was originally developed for the study of avalanches on highways in North America (British Columbia Ministry of Highways 1974, Armstrong 1981). Subsequently, the method has been applied to New Zealand conditions, in particular the Milford Road (Fitzharris and Owens 1980) and the Ball Hut Road (Fitzharris et al. 1984). In this report we modify the method so it can be applied to a walking track. The Index is used:

(a) to determine objectively how serious the avalanche danger is at each path and for the total of all paths along the Milford Track;

(b) to compare the hazard with that of highways;

(c) to determine the appropriate level of management and avalanche control;

(d) to indicate for which avalanche paths the management and control methods would have the greatest effect.

The avalanche hazard is the encounter probability of a walker being hit by an avalanche, and is a function of:

(a) the size and type of avalanche;

(b) the frequency of avalanche occurrence;

(c) the number of avalanche paths;

(d) the length of time a walker takes to cross the avalanche paths;

(e) the number of walkers who use the track.

It is normal to calculate the hazard assuming that there are no control measures, and to define the level of hazard as given in Table 2.

Table 2. Level of Avalanche Hazard as determined by the Hazard Index

Level of Hazard	Hazard Index
Very low	Less than 1
Low	1 to 10
Moderately high	10 to 100
High	Greater than 100

Encounter Probability

For each path, the probability of an encounter between a track walker and an avalanche in motion is

$$P_x = \frac{t_e}{t_x} \cdot \frac{1}{f_x} \cdot W$$

where:

P_x = probability of an encounter per person in the period x

t_e = time the walker is exposed to the potential avalanche. This is normally the time it takes to walk across the avalanche path, but may take into account additional time to visit some interesting natural feature or to admire the view.

t_x = time period (x) for which the hazard index is to be calculated.

f_x = frequency of avalanches in the period x

w = a weighting factor to represent the relative cost and consequences that would result from an accident involving an avalanche.

The Hazard Index for each period (x) is the sum of P_x for all paths, multiplied by the number of walkers in the period.

Values Used

For the Milford Track, the Hazard Index was calculated for two periods:

(a) for the Track season of November to March (t_x = 5 months). Encounter probabilities for this period are given the symbol P_s.

(b) for the winter period April to October (t_x = 7 months). Encounter probabilities for this period are given the symbol P_w.

Because avalanches which cross the Milford Track tend to be very large, and plunge from a great height, any encounter will bring death or very serious injury. Even for smaller paths found about the Mackinnon Pass, the consequences will seldom be less serious, because here avalanches are likely to carry a walker over steep bluffs, or far down the slope. Therefore, W is set equal to 10, which is equivalent to the human consequences if a vehicle on a highway was hit by an avalanche with deep snow. (British Columbia ministry of Highways, 1974).

Values of t_e were obtained in the field by observing the time walkers on the Track took to traverse each avalanche path. At a few sites, such as Hidden Lake and Sutherland Falls, allowance was made for the time spent sight-seeing. The times used assume that walkers are travelling at normal pace and do not stop within an avalanche path, except as noted above. Walkers who move more slowly, or who stop at other places, will increase the risk of an avalanche encounter to a value greater than reported here.

Values of f_x were assigned to each path during the mapping exercise. The numbers of people walking the Track were set at 7000 during the Track season, and 150 during the winter. The former figure is a reliable estimate for 1982-83 based on THC and Fiordland National Park bookings. The winter traffic is estimated from hearsay, and from occasional hut book entries, but could be larger. If the numbers using the Track increase in future years, it is a simple matter to recalculate the Hazard Index because it rises in direct proportion.

The Hazard Index is calculated for the Milford Track using both options for the descent from Mackinnon Pass: (a) the Main Track, and (b) the Emergency Track. It is assumed that all walkers visit Hidden Lake and the Sutherland Falls.

RESULTS OF THE HAZARD INDEX CALCULATION

The hazard index for the Milford Track during the walking season is calculated at 8.3 for the Main Track, and at 7.7, slightly less if the Emergency Track is used (Table 1). This assumes that 7000 walkers are using the Track. Therefore, there is a "**low**" avalanche hazard under present conditions. The index rises linearly with more walkers at the rate of 0.0012/person, but this is reduced by 7% should the Emergency Track be used. The hazard becomes "**moderately high**" when the numbers using the Track exceed 8500 during the season.

This assessment of low hazard is an underestimate for guides, rangers and other Track maintenance personnel, who because of their work, tend to spend longer periods within the avalanche paths. It is also an underestimate for early November and during late springs when avalanche activity is sustained.

The avalanches that contribute most to the hazard during the Track season are **Corkscrew**, **Zig-Zag** and **Pompolona** (Table 1). Other dangerous spots are at **Hidden Lake**, **Avalanche Creek**, **Waterfall**, **Nicolas**, **Balloon 1**, **Jervois**, **Elliot Wall**, and **Pepper**. **Balloon** 3 contributes significantly if the Emergency Track is used.

The hazard index for the winter season, when the estimated traffic on the Track is 150 people, is also "**low**" at 6.0. If the Emergency Track option is used it drops to 4.4 (Table 1). However, the hazard rises quickly with increased use, reaching "**moderately high**" when numbers exceed 250 people, and "**high**" for 2500 people. In winter, the most hazardous paths are **Jervois-Elliott Wall**, **Balloon 1**, **Balloon** 2, **Hidden Lake**, **Balloon** 5, **Final Leap** and **Zig-Zag** 6 (Table 1). **Balloon** 3 is also important if the Emergency Track is used.

A comparison of the hazard index with some highways and the track across the Manganui Gorge, Mt. Egmont, is shown in Table 3. The hazard to walkers on the Milford Track is considerably less than that to winter traffic on the Milford Road, but somewhat similar to that for vehicles on the Ball Hut Road.

It is accepted management practice to adopt the following responses to the different levels of hazard.

Very low hazard: posting of signs: "do not stop, avalanche area". No other action is necessary.

Low hazard: avalanche warning signs and occasional closures of the road or walking track are necessary.

Moderately high hazard: avalanche control is applied at selected sites, and supplemented by warnings and occasional closures.

High hazard: a full avalanche control programme is required. Frequent closures are applied according to the instructions of a specially appointed avalanche co-ordinator.

If these recommendations were applied to the Milford Track, then avalanche warning signs and closure of the Track at times of high avalanche danger should be implemented now. Some avalanche control will be needed at the more hazardous sites when the number of walkers exceed 8500 in a Track season, or when there is a late spring. Management responses for the Milford Track are considered in more detail in the next section.

Table 3. **Rating of some avalanche areas by Hazard Index and comparison with the Milford Track**

Area	**Average daily traffic**	**Hazard Index**
High hazard		
Rogers Pass, Canada*	900	335
Fraser Canyon, Canada	3000	140
Highway 550, U.S.A.	675	126
Moderately high hazard		
Pine Pass, Canada	400	53
Milford Road, N.Z.	80	46
Bear Pass, Canada	30	37
Bridge River, Canada	30	14
Low hazard		
Ball Hut Road, N.Z.	40	9
Milford Track, N.Z.	50	8
Bella Coola, Canada	12	5
Manganui Gorge, Mt. Egmont, N.Z.	160	2
Very low hazard		
Laidlaw, Canada	4400	0.4
Ningunsaw Pass, Canada	15	0.2

* Canadian data is from British Columbian Ministry of Highways (1974) so does not indicate current figures.

MANAGING THE AVALANCHE HAZARD ON THE MILFORD TRACK

The object of a hazard management plan is to reduce the risk to the walkers and service staff on the Track, yet keep the closure times to a minimum. There are three basic alternatives, which can be used in combination or singly.

1. Relocate the Track
2. Control the walking traffic
3. Control the avalanches

1. Relocation of the Track

This is possible at a few locations, and use of the Emergency Track is a good example. At present the Emergency Track descends from the Main Track at **Balloon** 3 and walkers spend 15 minutes at risk from its avalanches. We recommend that a new track be cut so that it does not include this path. It may be possible to relocate the track at **Corkscrew** so it veers away from the valley side. The track has previously been changed to avoid a potentially high hazard at **Swimming Pool**, and this detour should be maintained.

2. Control of walking traffic

The main opportunities for management of the avalanche hazard come from control of walkers.

(a) At times of extreme risk from avalanches, the Track should be closed, and the walkers be required to stay extra nights in their huts. The use of the Emergency Track should be encouraged at times of snow instability. Problems will arise in deciding when, and for how long, the Track should be closed. Formal methods need to be developed to assess the avalanche danger on the basis of snow and weather changes and on past experience. Thus the present observations of precipitation and temperature at Mintaro and Dumpling Huts should be maintained, and the information plotted daily to deduce snow stability. Observations of starting zone snow conditions should be made regularly by binocular, and occasionally by helicopter landings when finance or other activities permit. The mountain forecast and weather maps should be received daily at Te Anau, and this information relayed to all huts along the Track.

It is recommended that the park employee stationed at Mintaro be responsible for avalanche hazard evaluation and day to day decisions on opening and closing the Track. He is closest to the dangerous paths, and can most easily assess conditions on both sides of the Pass. An experienced ranger based in Te Anau, or the Milford Road avalanche forecaster, who has access to daily weather maps and the meteorological observations, should guide him and liaise with the THC Manager. The knowledge and experience of these people should be extended by encouraging them to attend avalanche courses, and by giving them time to plot and analyse past meteorological and avalanche information.

Radio communications for the length of the track and between THC and FNP need to be rationalised so information can easily be disseminated. Some form of communication radio is needed at the Pass shelter.

Those avalanche events which cross or nearly cross the Track need to be documented in a systematic manner. Each avalanche should be recorded by date, path, name, size and type, with notes on the weather situation. The data should be displayed so that knowledge of the relationships between avalanche behaviour and weather become apparent to those managing the Track. In this way, rules for forecasting avalanches and hence Track closures can be deduced.

(b) When conditions are not extreme, but there is some avalanche danger, the walkers should be guided by THC personnel or park assistants, who should learn the location of the avalanche paths, and ensure that no walker lingers in dangerous areas.

(c) A third way to control walkers is with the use of signs. They educate walkers as to the potential hazard and warn them not to stop on avalanche paths. Warning signs are essential for the most active paths from **Pompolana** to **Quintin** and at **Pepper** and **Hidden Lake**.

(d) If the Track is to take more people, the season should be extended into Autumn, when the danger of avalanche is slight, and not into Spring, where the danger increases markedly.

3. Control of avalanches

This is not presently warranted on the Milford Track, except in late spring seasons with heavy snow. Then a clean-up operation, whereby the most hazardous paths are bombed from a helicopter, would increase safety. This should preferably be done before the opening of the track season, and is likely to involve those paths that start on the Jervois glacier and those in the vicinity of Corkscrew.

AVALANCHE SAFETY

THC guides and FNP staff are at greater risk from avalanche than indicated here, because they use the Track repeatedly and before the Track season opens. They should wear rescue beacons in October and November, and at other times whenever the avalanche hazard is high. In the event of an avalanche burial, the use of beacons will mean a quicker finding of the victim, so that the rescuers are exposed for the shortest possible time. Experience also shows that an avalanche victim's chances of survival diminish rapidly with burial time. Fifty percent of buried victims perish in the first half hour, so speed of rescue is important.

Recent avalanche fatalities in Fiordland have highlighted the need for a defined avalanche rescue plan which is well known to the Police and staff of both FNP and THC. It should include the steps to be taken in the event of an accident, identify who will be responsible for organising the rescue, and establish an orderly set of procedures to rescue the victims. Avalanche rescue equipment stores should be maintained at both Mintaro and Quintin Huts. A practice rescue exercise should be conducted once a year to familiarise new Track staff with procedures for rescue and the avalanche hazard, and to test communications between different parts of the Track, THC and FNP.

SUMMARY AND RECOMMENDATIONS

A total of 56 avalanche paths cross the Milford Track, so that during their three day tramp, walkers spend almost four hours at risk. With the present volume of walkers, the hazard index is calculated as "low" for both the Track season and for the winter. The hazard will become "moderately high" when 8500 or more use the Track in the walking season, or if more than 250 people use it during winter. Most hazard during the walking season comes from **Corkscrew, Zig-Zag** and **Pompolana** avalanche paths, although **Hidden Lake, Avalanche Creek, Waterfall, Nicolas, Balloon, Jervois,** and **Elliot Wall** can also be dangerous. For much of the walking season avalanche activity across the Track is very infrequent, except in November (or later if it has been a cold, snowy spring,) and after heavy snowfalls. In winter and spring there is much greater risk, and several of the avalanche paths can each eject more than one hundred thousand tonnes of snow onto the valley floor. The small tarns at Hidden Lake and Swimming Pool are impact pits where avalanches land with explosive impact.

We make the following recommendations in order to improve avalanche safety along the Milford Track:

1. When snow and weather conditions create a high risk of avalanche, the Milford Track should be closed.

2. The responsibility for closing and reopening the Track should be vested in a trained person based at Mintaro hut.

3. He should be supplied with all available information on weather observations, mountain forecasts, weather maps, and current snow conditions.

4. He should be responsible to, and supported by, a liaison group in Te Anau which includes a member of the Tourist Hotel Corporation and Fiordland National Park.

5. Periodic observations should be made of the snowpack near the **Corkscrew** and **Jervois** starting zones.

6. Direct control of avalanches with explosives is not warranted unless the snow season is late, and avalanches threaten the opening of the Track.

7. At times when the Track is open, but there is a some risk of avalanches, the use of the Emergency Track is recommended. However, its present position needs to be relocated to avoid the **Balloon 3** avalanche path.

8. If the Track season is to be lengthened, then it should be extended into the autumn months. It should not open earlier than at present.

9. Signs should be placed on the Track indicating the most dangerous paths and advising walkers not to stop.

10. Fiordland Park and Tourist Hotel Corporation staff are at greatest risk on the Track. They should be encouraged to attend avalanche courses and wear rescue beacons in October and November, and at other times of high avalanche risk.

11. Radio communication along the Track needs to be rationalised so that in the event of an accident all rescuers from the THC and FNP can use a common frequency.

12. Caches of avalanche rescue equipment need to be established at Quintin and Mintaro huts.

13. There should be a clearly defined, written rescue plan that is practised once a year.

ACKNOWLEDGEMENTS

We are very grateful to Mr Bill Neilsen, Manager, and all the staff of Tourist Hotel Corporation who provided accommodation, experience and good company while we were mapping avalanches on the Milford Track. We also thank Mr Paul Green, Chief Ranger Fiordland National Park and his staff for their help and co-operation. To Zygmund Kepka, our special thanks for his help as a knowledgeable, amusing and tireless field worker - his long experience and interest in avalanches greatly enhanced the worth of this atlas. Thanks also to Mark Mabin who assisted with fieldwork and photography and to the cartographic and photographic staff, Department of Geography, University of Canterbury.

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APPENDIX

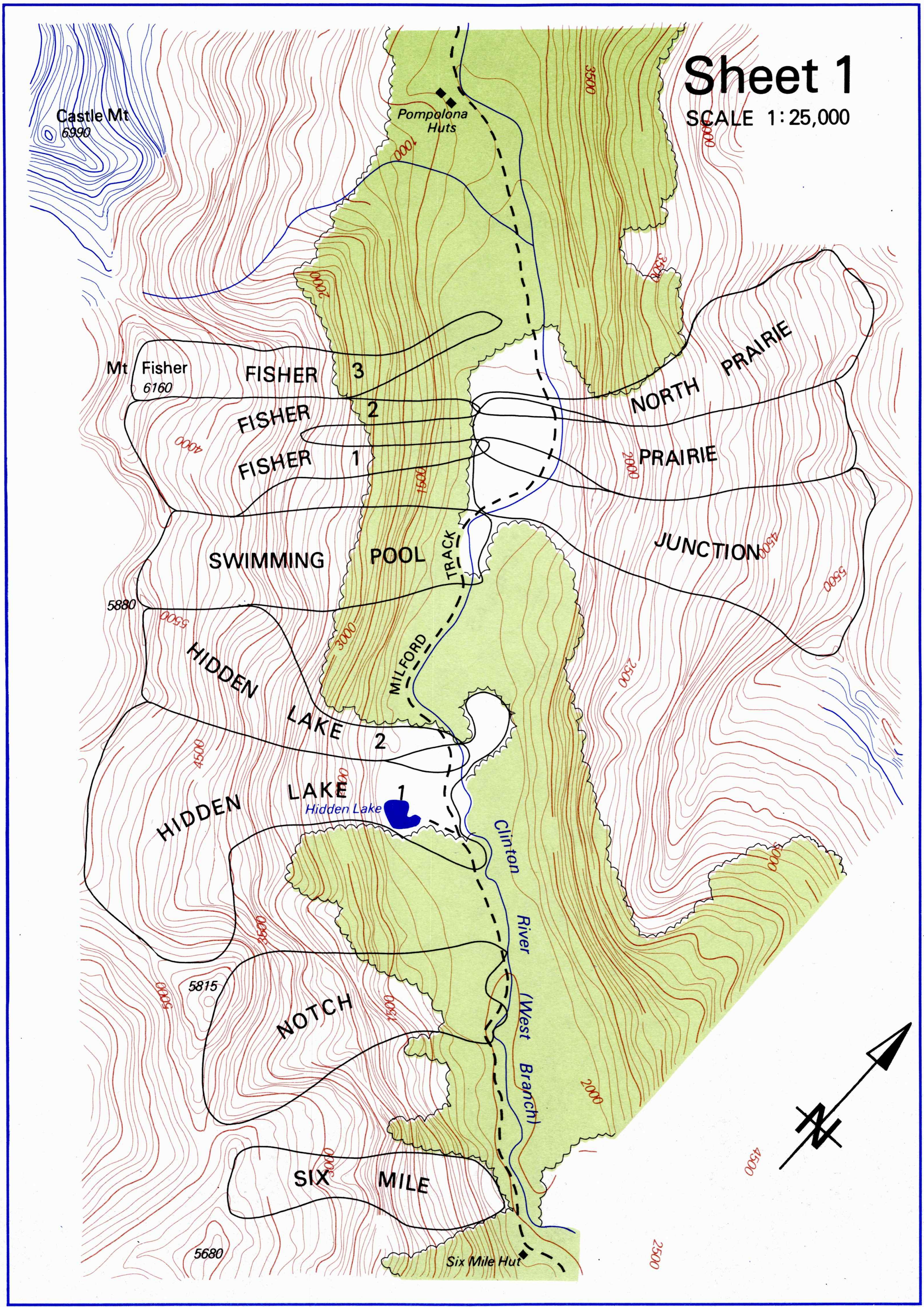
SNOW AVALANCHE ATLAS OF THE MILFORD TRACK

GENERAL INTRODUCTION

This avalanche atlas is a guide to the snow avalanche paths located along the Milford Track. The atlas standardises the names and definitions of the various avalanche paths. These names can be used to report avalanche occurrence and to instruct walkers and new staff as to the hazardous areas.

The avalanche atlas contains:

- o Detailed maps showing location of each path
- o Oblique aerial photographs of each path
- o Summaries which describe the main characteristics of each path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NORTH PRAIRIE
PRAIRIE
SWIMMING POOL
JUNCTION
MILFORD TRACK
5880
HIDDEN LAKE 2
HIDDEN LAKE 1
Hidden Lake
Clinton River (West Branch)
NOTCH
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SIX MILE
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Sheet 2

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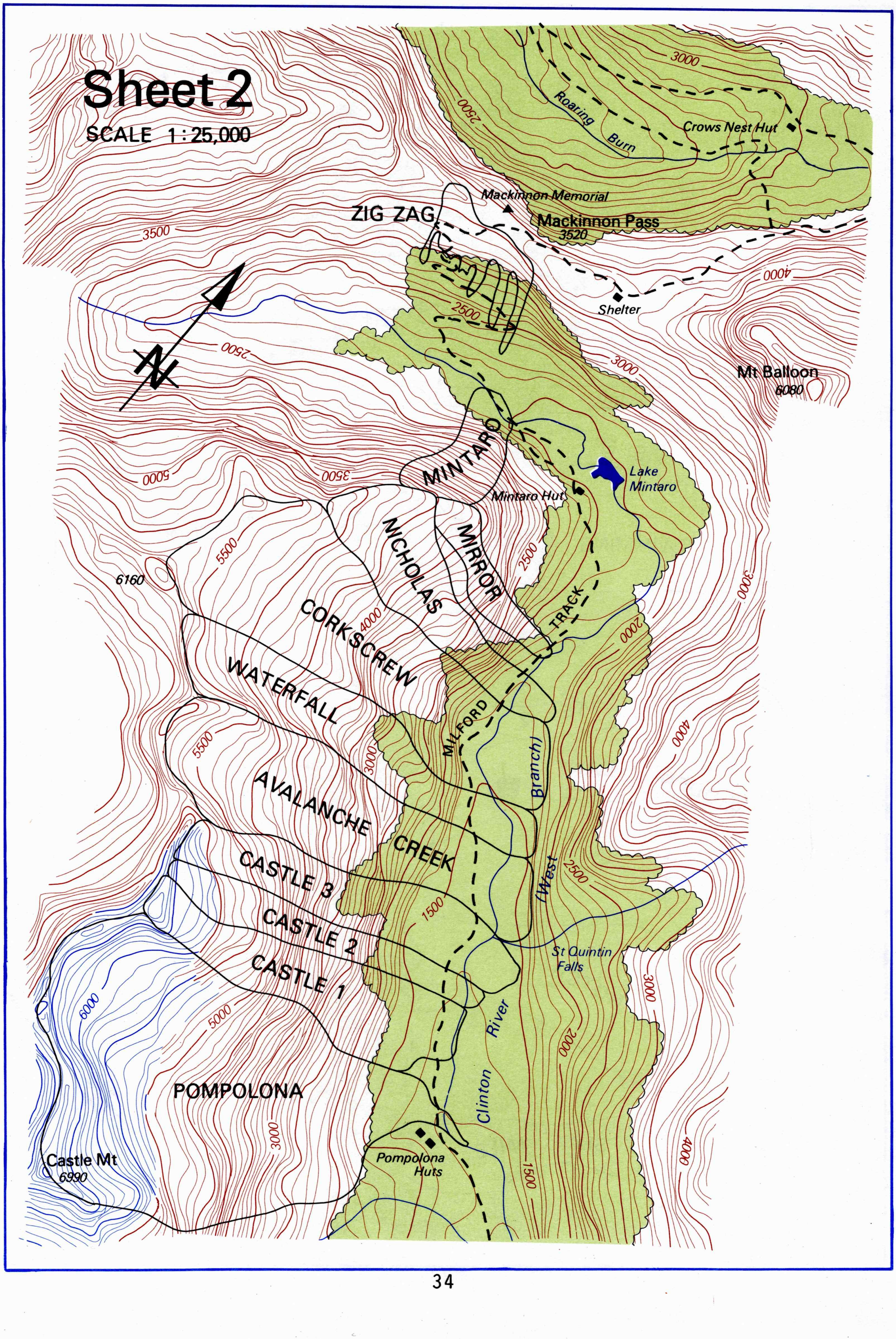

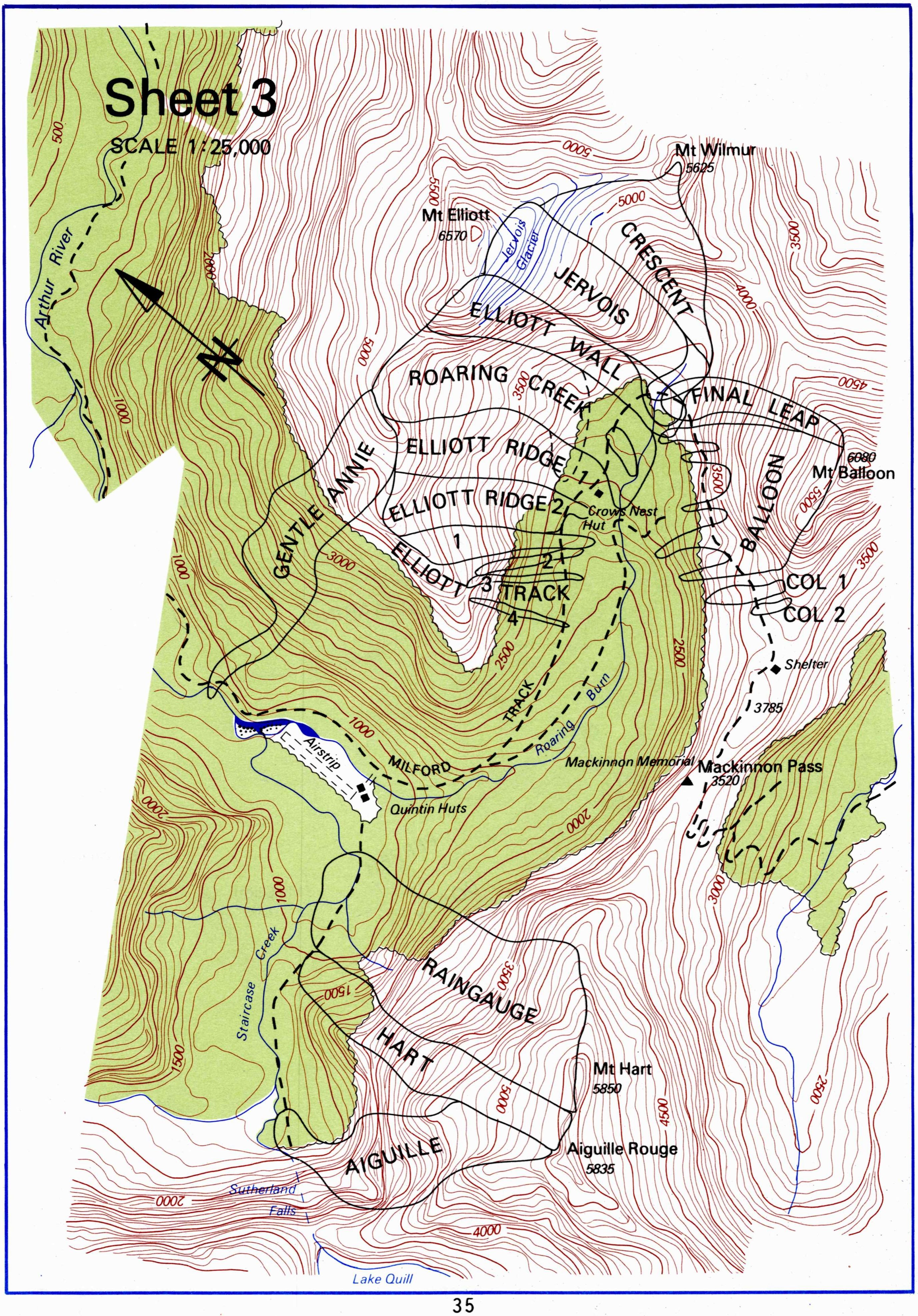

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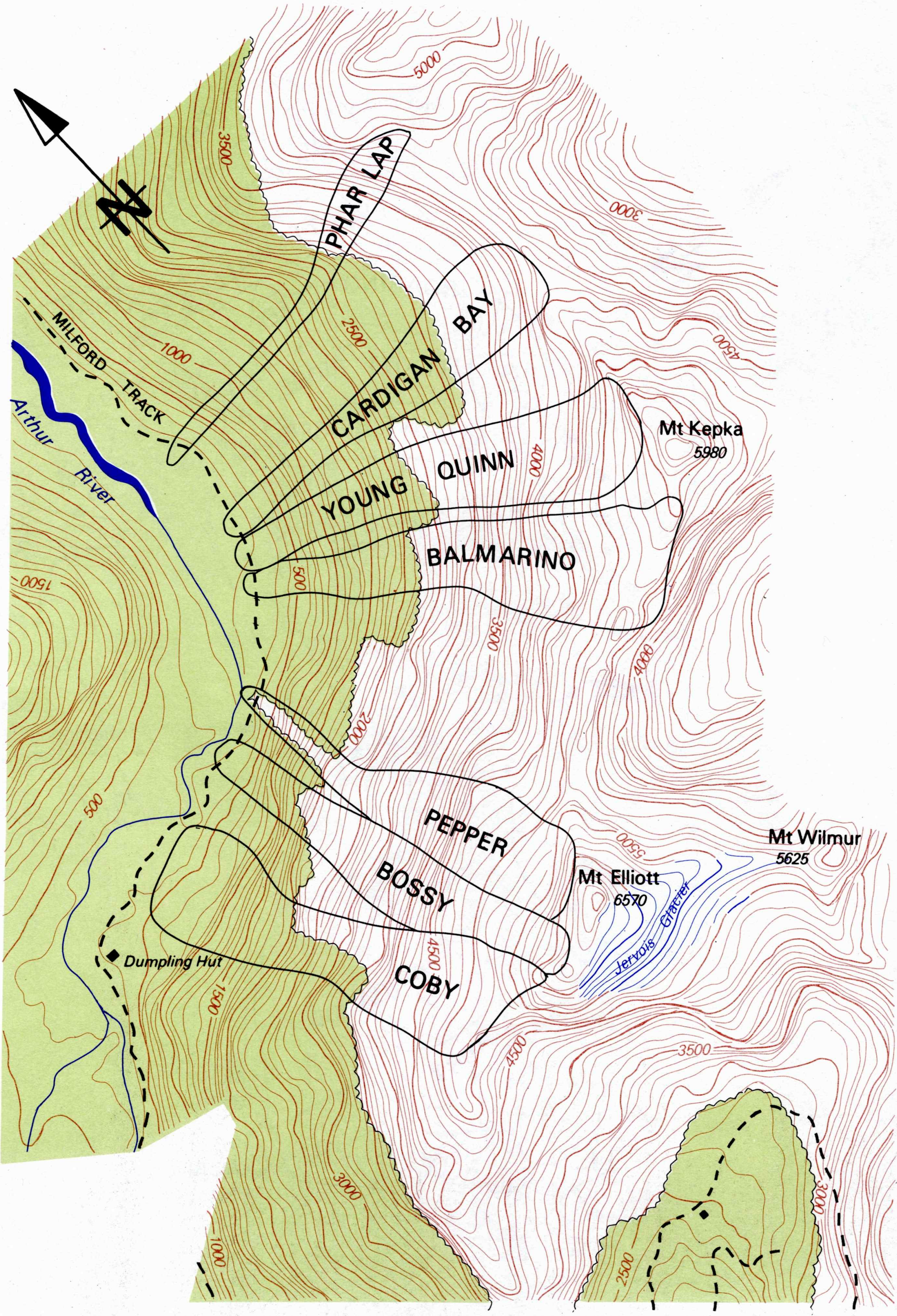
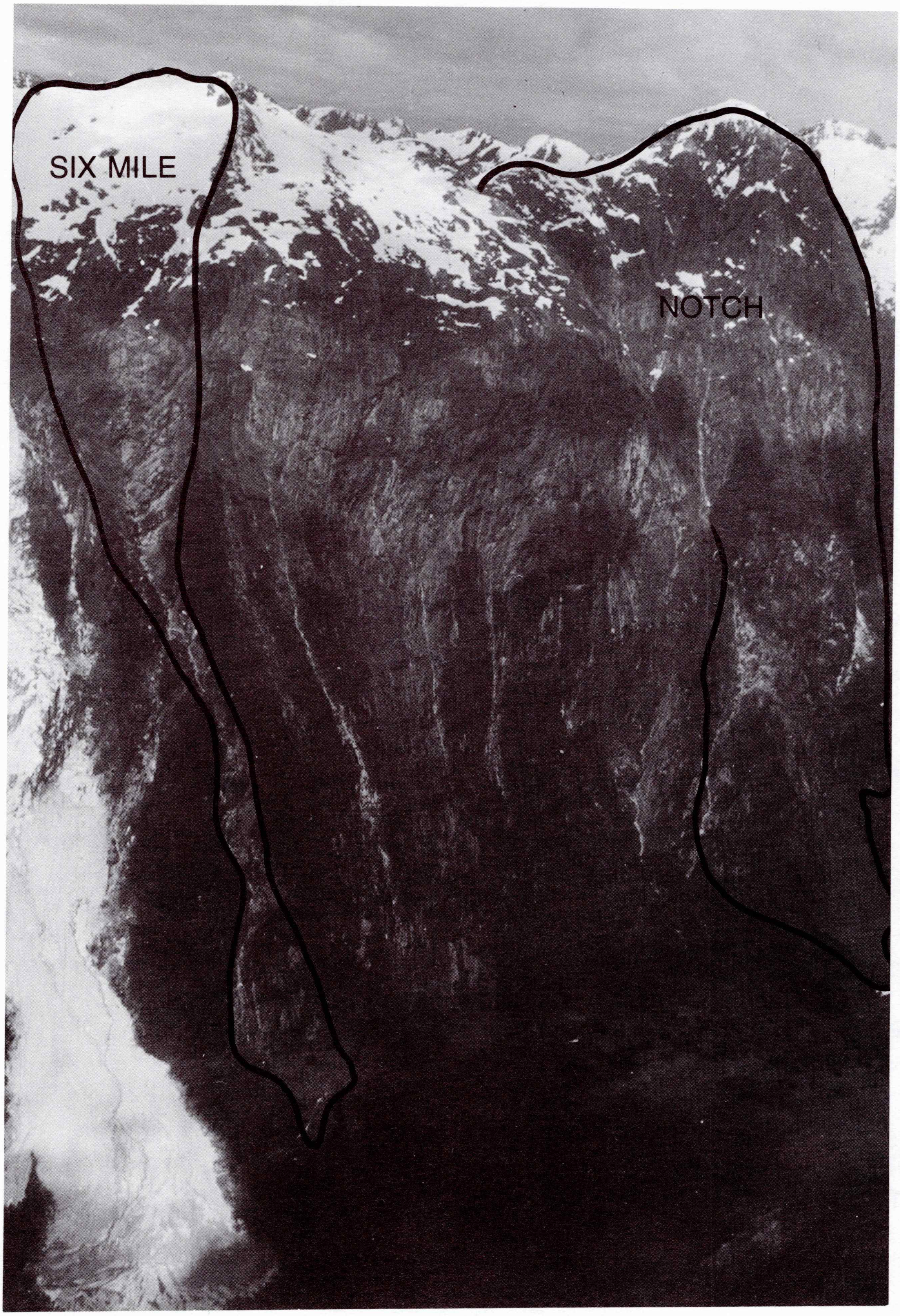


AVALANCHE PATHS OF THE
MILFORD TRACK

Oblique aerial photographs and descriptions

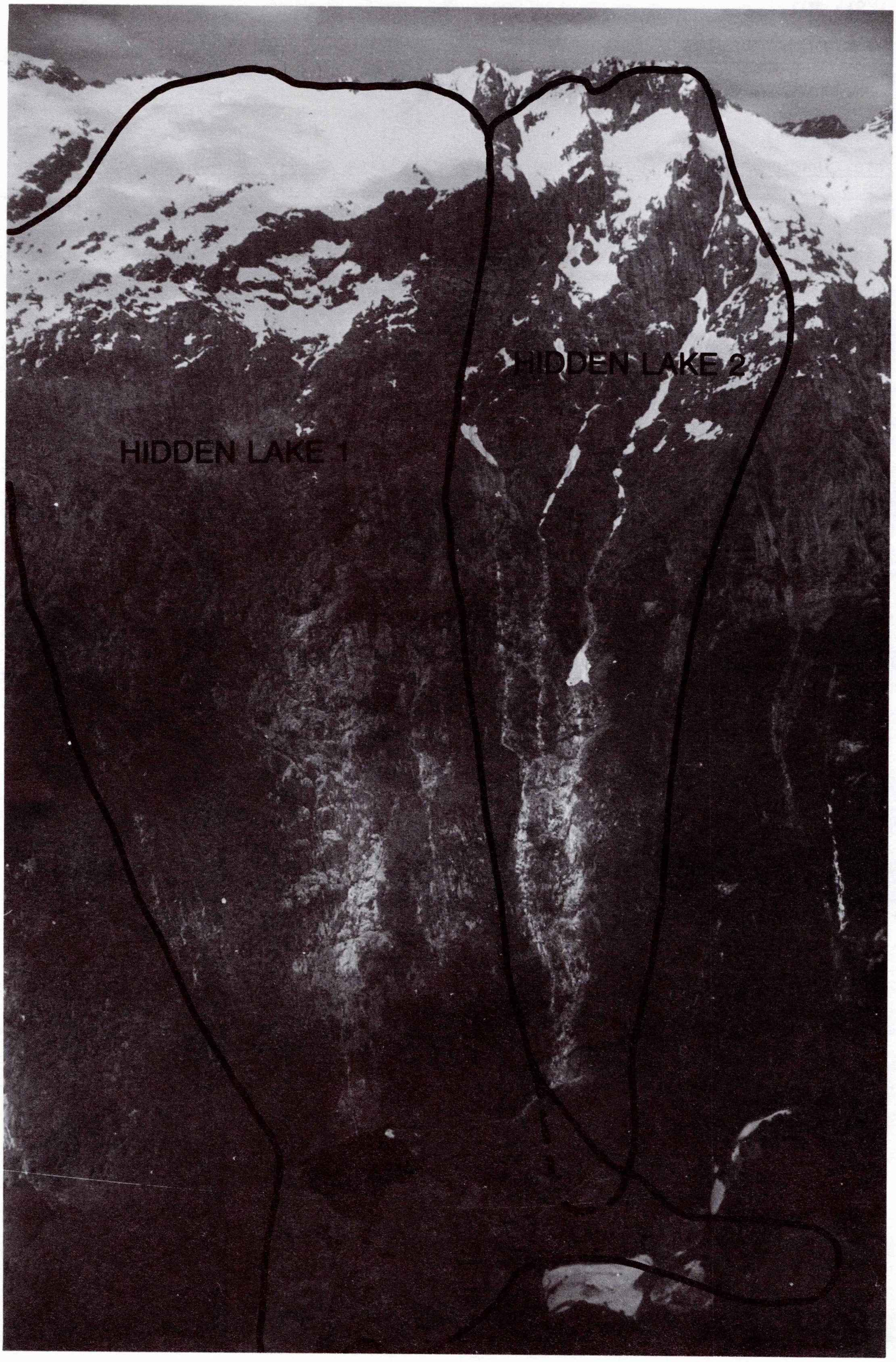

SIX MILE
NOTCH

1.SIX MILE

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 32° Elevation = 1620 - 1250m Area = 0.17 km^2 Aspect = NE Terrain: Shallow bowl leading to ridge crest.	Year: Once in 30 years. Track season: Once in 50 years.
TRACK	COMMENTS
Slope = 53° Elevation = 1250 - 430m Terrain: Partially confined in upper section.	Small to moderate-sized path with a shallow bowl-shaped starting zone and a narrow steep track. The starting zone will load in south-west storms but runs relatively infrequently.
RUN-OUT ZONE	
Slope = 27° Elevation = 430 - 310m Terrain: On edge of small fan.	

2. NOTCH

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 52° Elevation = 1770 - 1250m Area = 0.26km^2 Aspect = NE Terrain: Bowl with steep slope leading up to peak.	Year: Once in 30 years. Track season: Once in 50 years.
TRACK	COMMENTS
Slope = 47° Elevation = 1250 - 460m Terrain: Confined in two gullies.	Moderate-sized steep starting zone extending to 1770m, with the track consisting of two gullies separated by a partially vegetated ridge. Large avalanches are relatively infrequent, probably because of the steepness of the starting zone.
RUN-OUT ZONE	
Slope = 16° Elevation = 460 - 310m Terrain: Fan.	



HIDDEN LAKE 2
HIDDEN LAKE 1

3. HIDDEN LAKE 1

STARTING ZONE

Slope = 35° Elevation = 1740 - 1250m

Area = 0.76km^2 Aspect = NE

Terrain: Large wide bowl.

ESTIMATED FREQUENCY

Year: Once in 30 years.
Once in 0.3 years to lake track.

Track season: Once in 100 years.
Once in 20 years to lake track.

TRACK

Slope = 50° Elevation = 1250 - 340m

Terrain: Broad and unconfined.

RUN-OUT ZONE

Slope = 2° Elevation = 340 - 315m

Terrain: Valley bottom with avalanche tarn impact and drainage features.

COMMENTS

A large path with a broad bowl-shaped starting zone and a steep unconfined path plunging steeply to the valley bottom where the maximum extent is clearly marked by vegetation and the most frequently affected area by the lake and associated smaller ponds. The lake is an avalanche impact crater.

4. HIDDEN LAKE 2

STARTING ZONE

Slope = 48° Elevation = 1740 - 1220m

Area = 0.28km^2 Aspect = NE

Terrain: Three steeply sloping benches.

ESTIMATED FREQUENCY

Year: Once in 30 years.

Track season: Once in 100 years.

TRACK

Slope = 46° Elevation =1220 - 340m

Terrain: Partially confined in upper section.

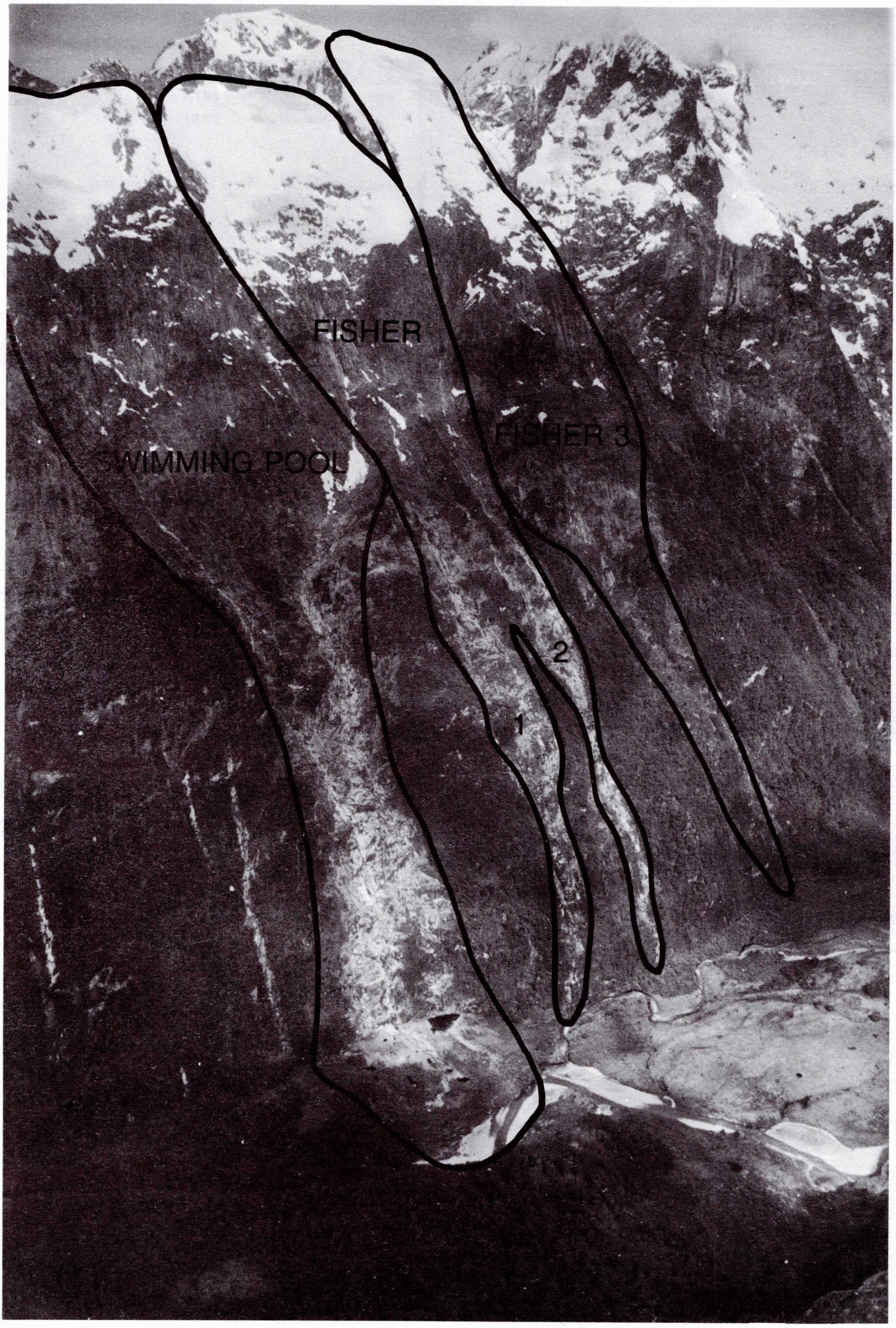
RUN-OUT ZONE

Slope = 3° Elevation = 340 - 315m

Terrain: Valley bottom.

COMMENTS

A smaller path with three distinct starting zones leading to partially confined tracks which merge into a less confined lower track.


FISHER
FISHER 3
SWIMMING POOL
2
1

5. SWIMMING POOL

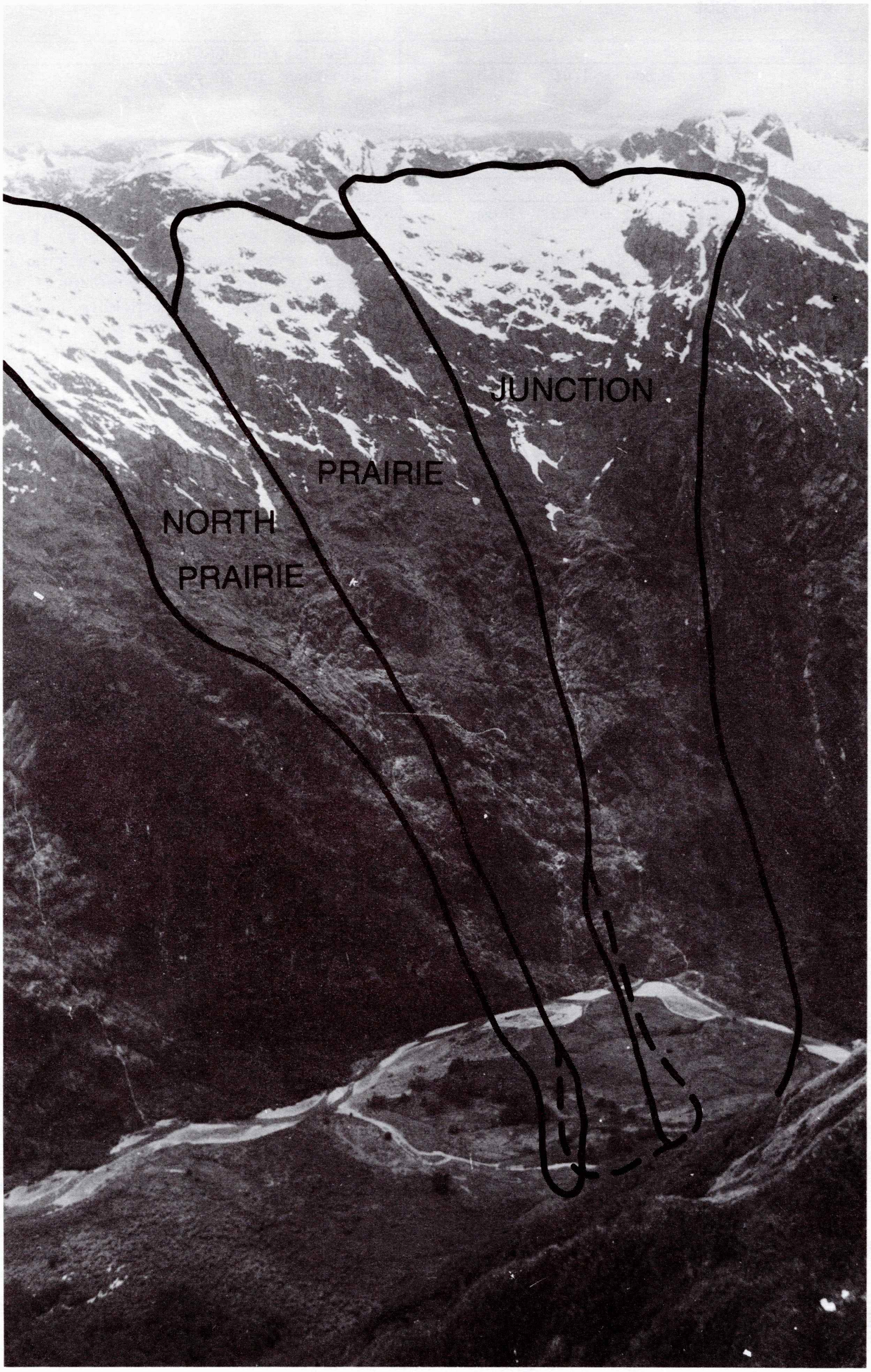
STARTING ZONE	ESTIMATED FREQUENCY
Slope = 43° Elevation = 1740 - 1340m Area = 0.21km^2 Aspect = NE Terrain: Shallow bowl.	Year: Once in 20 years. Track season: Once in 50 years.
TRACK	COMMENTS
Slope = 47° Elevation = 1340 - 340m Terrain: Partially confined in upper section.	A small to moderate-sized path with a moderate level of activity. Estimated frequency assumes that the walking track is close to the river and not near the pool where occurrence is much more frequent.
RUN-OUT ZONE	
Slope = 3° Elevation = 340 - 320m Terrain: Valley bottom with clear impact features.	

9, 10. FISHER 1, 2

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 33 + 36° Elevation = 1830 - 1370m Area = 0.30km^2 Aspect = NE Terrain: Well defined shallow bowl.	Year: Once in 20 - 50 years. Track season: Once in 20 - 50 years.
TRACK	COMMENTS
Slope = 43 + 49° Elevation = 1370 - 340m Terrain: Unconfined but narrowing downslope.	Small to moderate starting zone with relatively narrow tracks. Starting zone could load with winds from NW to SW. Moderate occurrence reflects the fact that the track is confined to the valley side.
RUN-OUT ZONE	
Slope = 5° Elevation = 340 - 330m Terrain: Small fans at intersection of valley side and bottom.	

11. FISHER 3

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 33° Elevation = 1830 - 1370m Area = 0.17km^2 Aspect = NE Terrain: Plane slope on shoulder of Mt. Fisher.	Year: Once in 30 years. Track season: Once in 30 years.
TRACK	COMMENTS
Slope = 47° Elevation = 1370 - 360m Terrain: Unconfined.	As for Fisher 1, 2.
RUN-OUT ZONE	
Slope = 4° Elevation = 360 - 340m Terrain: Small fan.	


JUNCTION
PRAIRIE
NORTH
PRAIRIE

6. JUNCTION

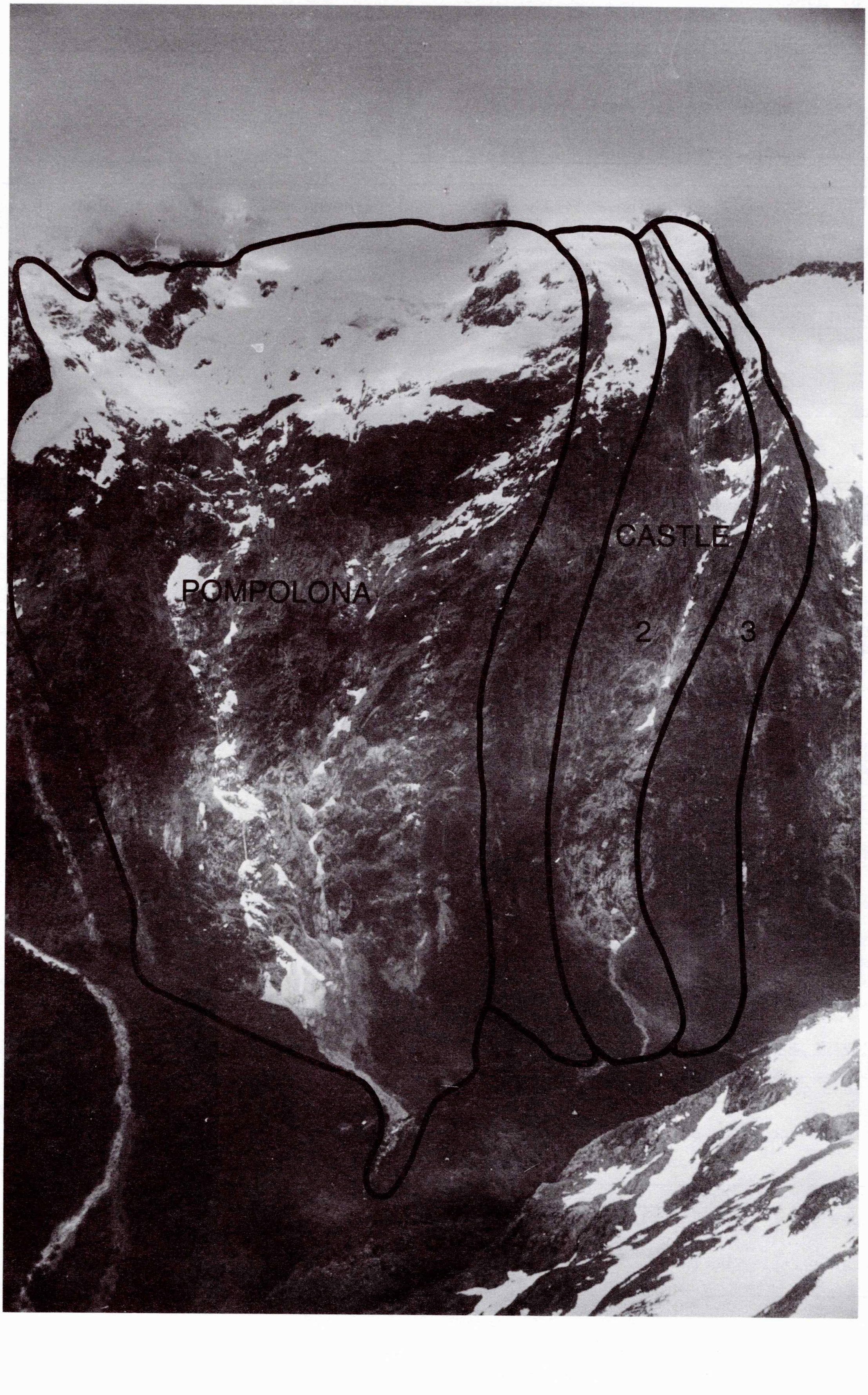
STARTING ZONE	ESTIMATED FREQUENCY
Slope = 39° Elevation = 1710 - 1370m Area = 0.34km^2 Aspect = SW Terrain: Shallow irregular bowl.	Year: Once in 30 years. Track season: Nil.
TRACK	COMMENTS
Slope = 43o Elevation = 1370 - 400m Terrain: Broad but partially confined.	Although this path is relatively large, it has a small effect on the present location of the walking track. The path's aspect means that large snow accumulation in the starting zone is unlikely.
RUN-OUT ZONE	
Slope= 7° Elevation = 400 - 330m Terrain: Valley bottom.	

7. PRAIRIE

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 41° Elevation = 1680 - 1370m Area = 0.16km^2 Aspect = SW Terrain: Irregular steep slope.	Year: Once in 30 years. Track season: Nil.
TRACK	COMMENTS
Slope = 45° Elevation = 1370 - 370m Terrain: Irregular and unconfined.	A slightly smaller path with a less well defined and lower elevation starting zone.
RUN-OUT ZONE	
Slope = 4° Elevation = 370 - 330m Terrain: Valley bottom.	

8. NORTH PRAIRIE

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 34° Elevation = 1710 - 1370m Area = 0.24km^2 Aspect = SW Terrain: Shallow basin.	Year: Once in 30 years. Track season: Nil.
TRACK	COMMENTS
Slope = 43° Elevation = 1370 - 370m Terrain: Irregular and unconfined.	A moderate-sized starting zone with relatively small effect on the walking track. Could possibly load in N and NW storms. Track angles slightly less than average, thus decreasing likelihood of long run-out.
RUN-OUT ZONE	
Slope= 4° Elevation = 370 - 330m Terrain: Valley bottom.	


CASTLE
POMPOLONA
1
2
3

12. POMPOLONA

STARTING ZONE

Slope = 38° Elevation = 2070 - 1370m

Area = 1.15km^2 Aspect = NE

Terrain: Large wide though irregular bowl.

TRACK

Slope = 47° Elevation = 1370 - 610m

Terrain: Broad unconfined slope.

RUN-OUT ZONE

Slope = 18° Elevation = 610 - 390m

Terrain: Talus and alluvial fan.

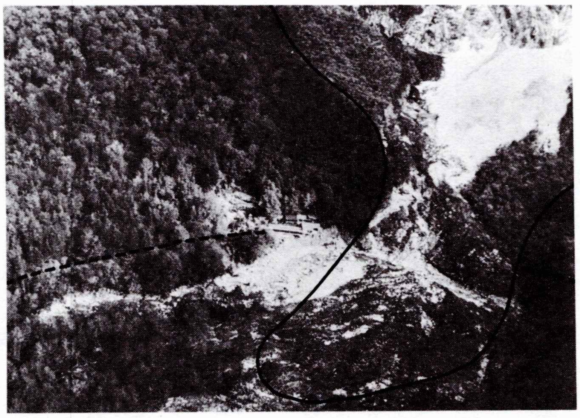
ESTIMATED FREQUENCY

Year: Once in 30 years along track. Five per year in central section.

Track season: Once in 50 years along track. Once per year in central section.

COMMENTS

A very large and active path. The starting zone is an irregular basin containing a decaying icefield. The track is quite steep and rough and leads to run-out zone made up of rockfall and avalanche and alluvial deposits. Although the original Pompolona hut site is very close to the path, it was protected by a small ridge. Indirect damage to the old hut was caused in October 1983 by damming of the Clinton River, with erosion of the bank following breaching of the dam. (see below)



13, 14, 15. CASTLE 1, 2, 3

STARTING ZONE

Slope = 38 - 40° Elevation = 2040 - 1520m

Area = 0.40km^2 Aspect = NE

Terrain: Steeply sloping irregular benches.

TRACK

Slope = 58 - 59° Elevation = 1520 - 490m

Terrain: Unconfined (1,3) and partially confined (2).

RUN-OUT ZONE

Slope = 4 - 11° Elevation = 490 - 410m

Terrain: Fans.

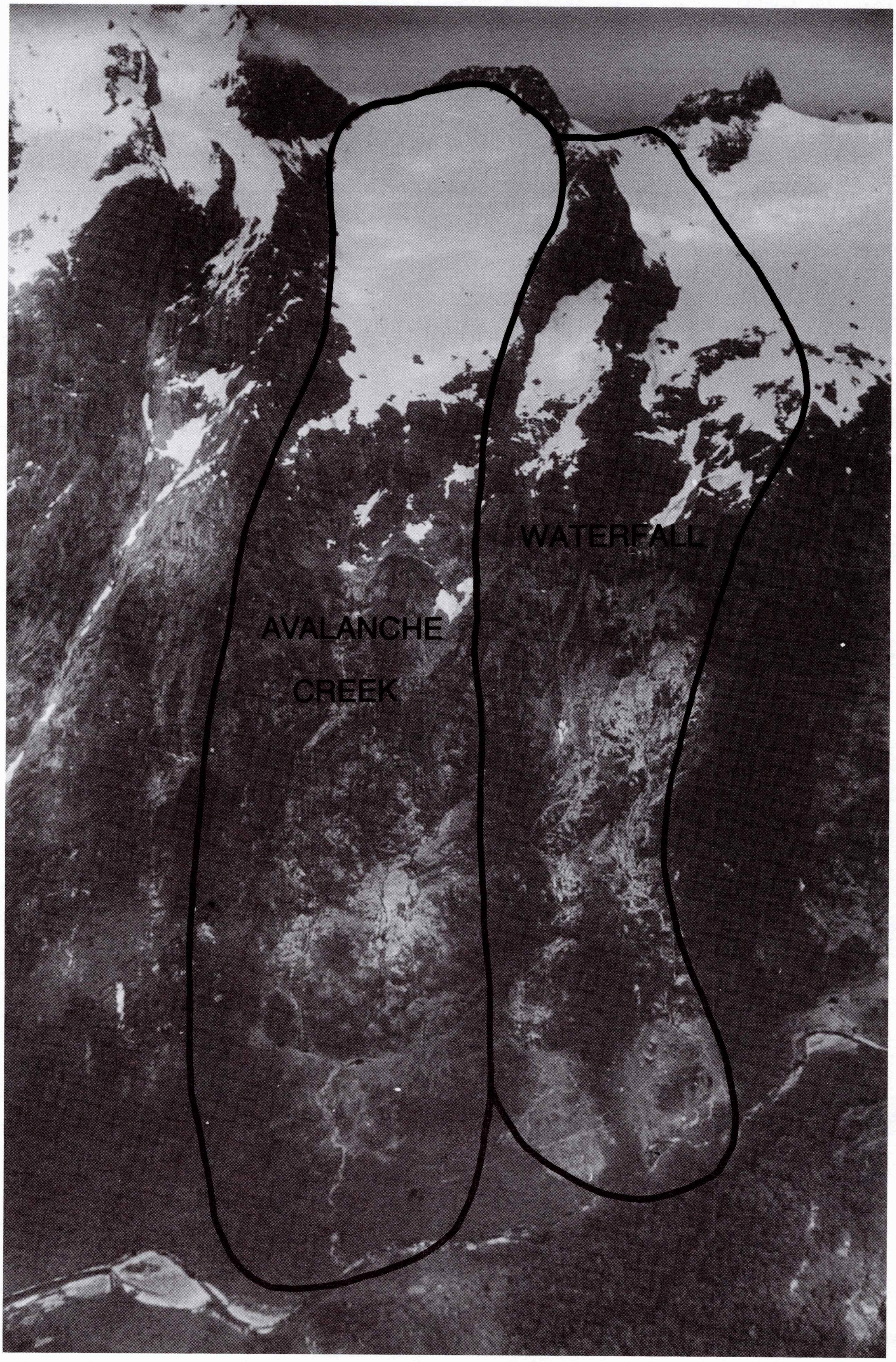
ESTIMATED FREQUENCY

Year: Once in 20-50 years along track. Five per year in central section.

Track season: Once in 50-100 years. Once per year in central section.

COMMENTS

Moderate-sized path with steep track. High frequency in the central section means that the path could be dangerous, particularly in westerly storms.

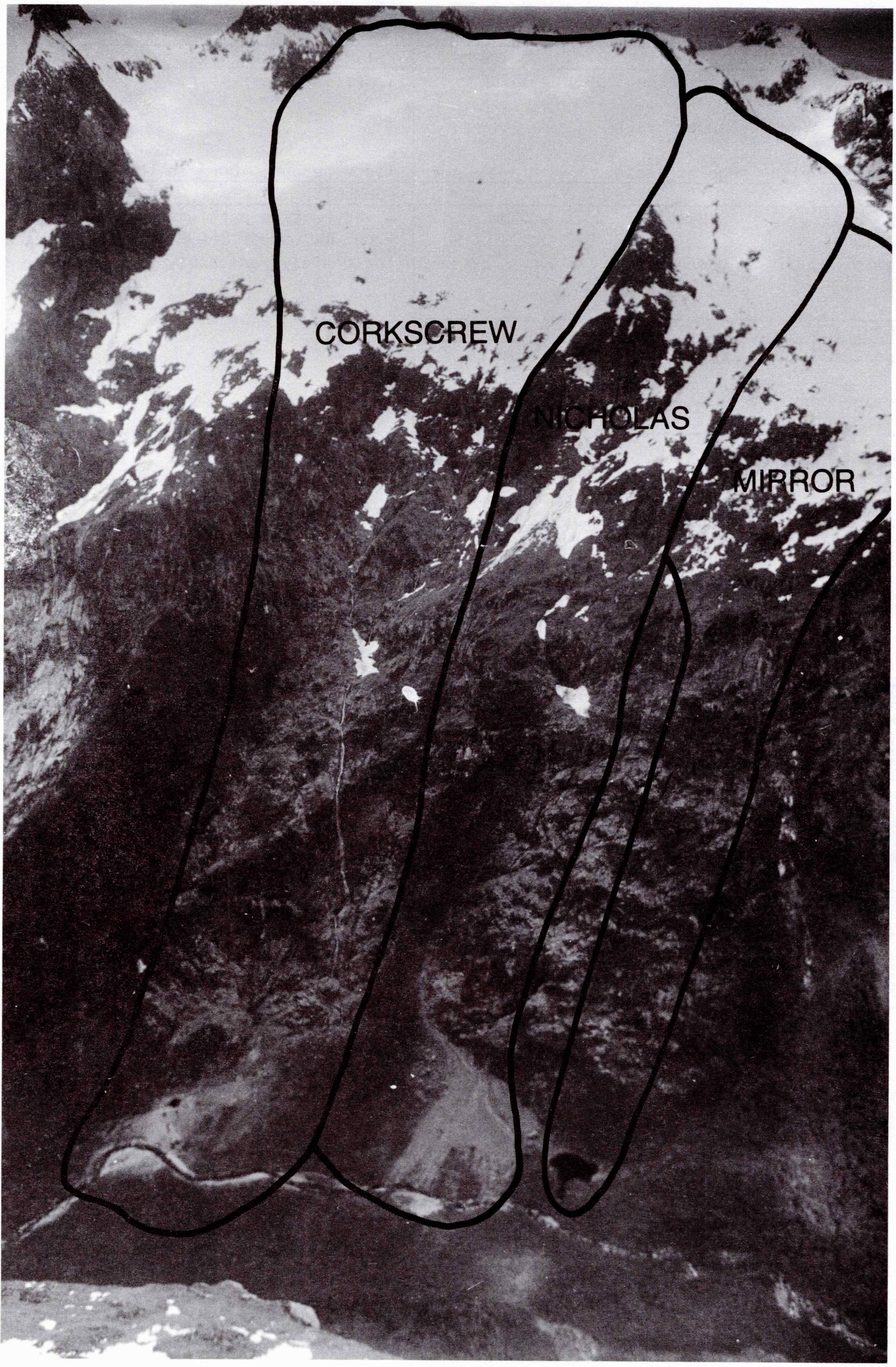

WATERFALL
AVALANCHE
CREEK

16. AVALANCHE CREEK

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 32° Elevation = 1830 - 1370m Area = 0.37km^2 Aspect = ENE Terrain: Shallow regular basin.	Year: Twice per year. Track season: Once in three years.
TRACK	COMMENTS
Slope = 51° Elevation = 1370 - 520m Terrain: Rough and unconfined.	A very active path with a smooth starting zone and rough track. Walking track is fortunately reasonably well down the fan.
RUN-OUT ZONE	
Slope = 10° Elevation = 520 - 430m Terrain: Partly vegetated fan.	

17. WATERFALL

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 33° Elevation = 1740 - 1220m Area = 0.27km^2 Aspect = ENE Terrain: Steep benches.	Year: Once in 10 years. Twice per year in central section. Track season: Once in 20 years. Once in three years in central section.
TRACK	COMMENTS
Slope = 39° Elevation = 1220 - 490m Terrain: Rough and unconfined.	An active path with a broken starting zone and rough track + run-out divided into two zones. The walking track is quite exposed and dangerous.
RUN-OUT ZONE	
Slope = 19° Elevation = 490 - 460m Terrain: Sparsely vegetated fan.	


CORKSCREW
NICHOLAS
MIRROR

18. CORKSCREW

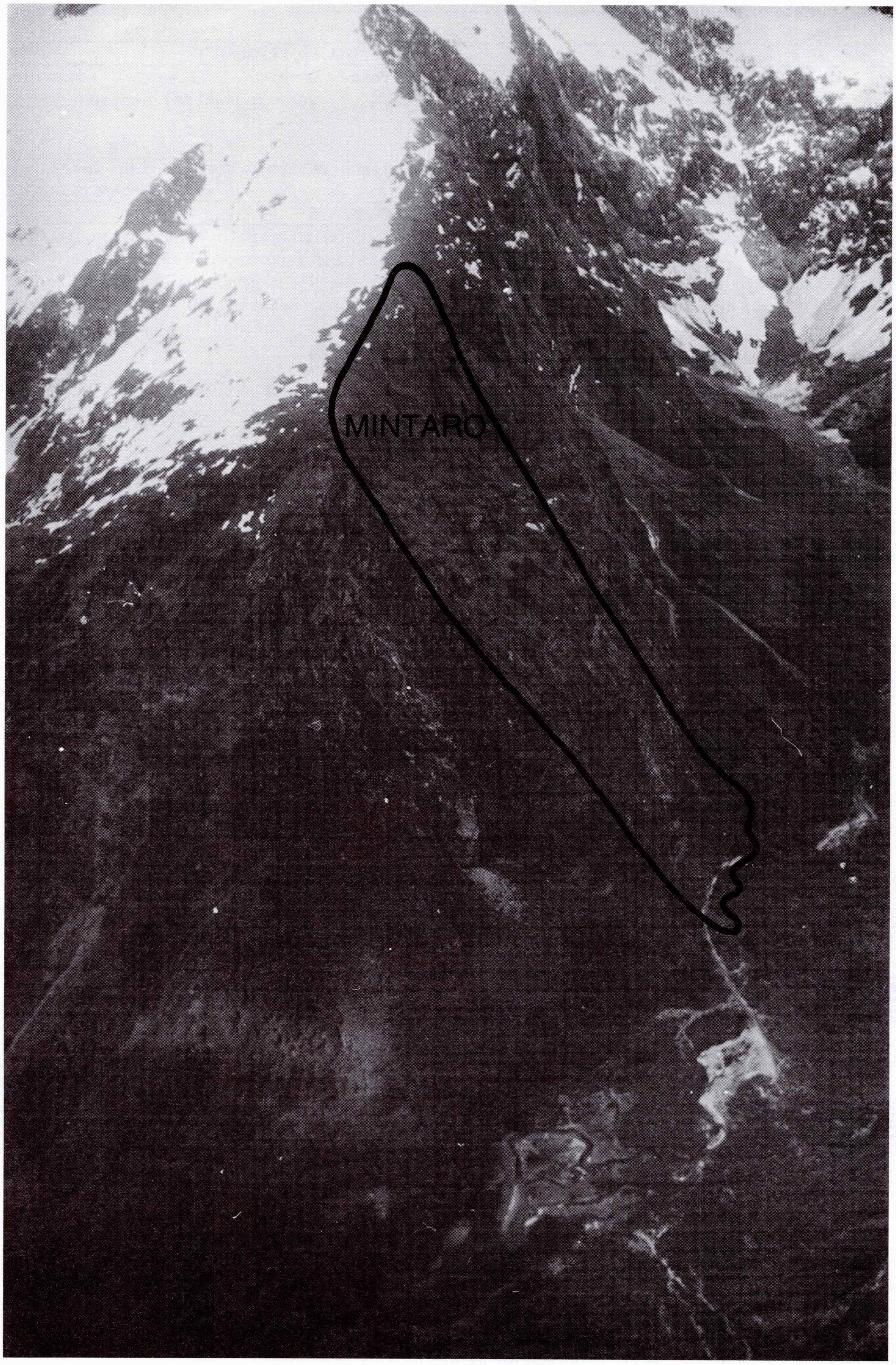
STARTING ZONE	ESTIMATED FREQUENCY
Slope = 29° Elevation = 1770 - 1220m Area = 0.55km^2 Aspect = NE Terrain: Smooth bowl.	Year: Once in five years. Five times a year in central section. Track season: Once in two years. Twice a year in central section.
TRACK	COMMENTS
Slope = 48° Elevation = 1220 - 510m Terrain: Broad and partially confined.	A dangerous path with a smooth shallow starting zone. Westerly and south-westerly storms will cause lee slope loading. Activity is high and the walking track is confined to a narrow section of the fan.
RUN-OUT ZONE	
Slope = 8° Elevation = 510 - 460m Terrain: Small fan.	

19. NICHOLAS

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 32° Elevation = 1620 - 1280m Area = 0.20km^2 Aspect = E Terrain: Irregular benches.	Year: Once per year. Track season: Once in five years.
TRACK	COMMENTS
Slope = 46° Elevation = 1280 - 520m Terrain: Irregular and partly confined.	A moderately active, though not large avalanche. Starting zone is slightly lower and smaller than those to the south.
RUN-OUT ZONE	
Slope = 29° Elevation = 520 - 490m Terrain: Small fan.	

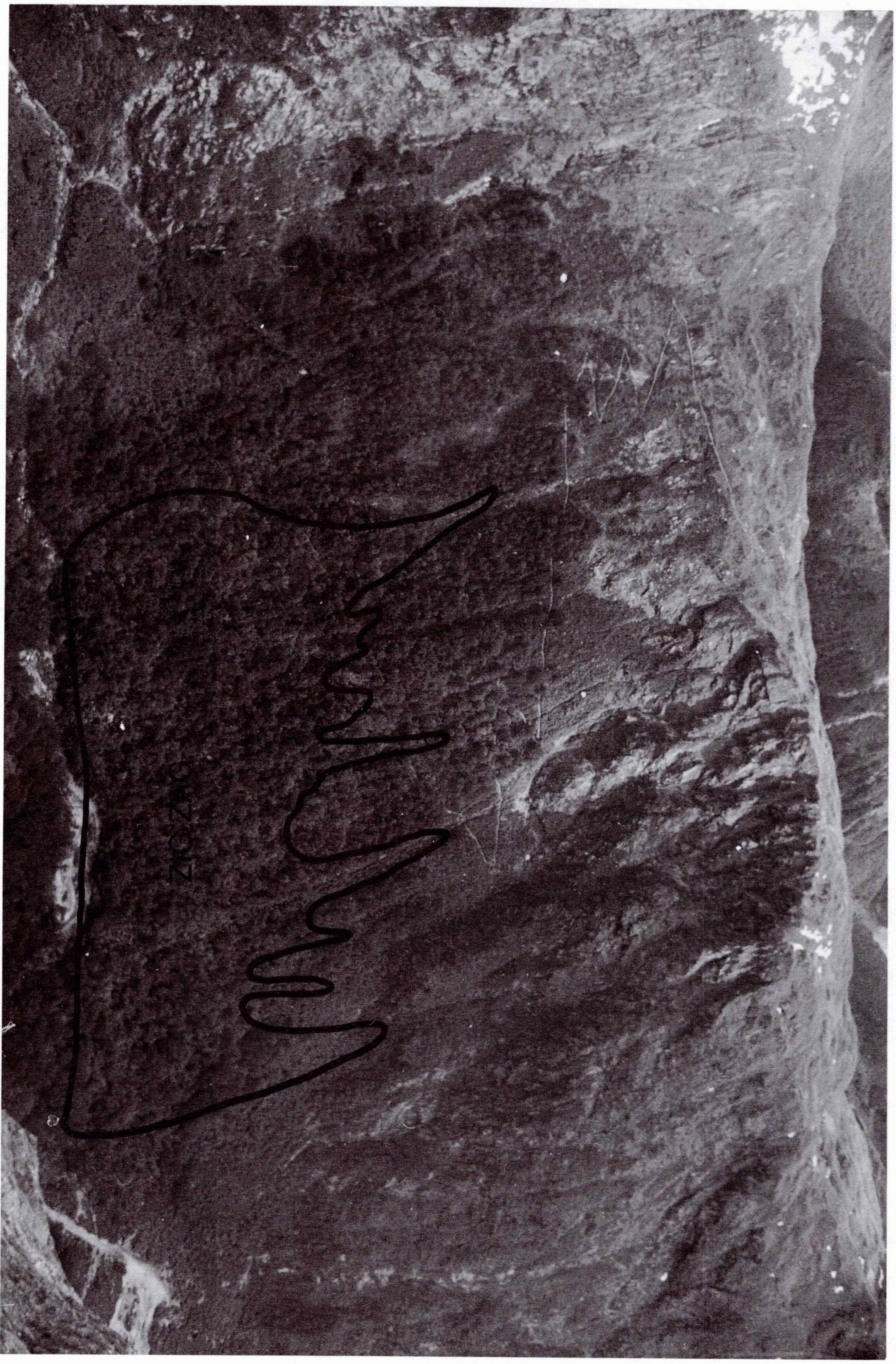
20. MIRROR

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 31° Elevation = 1370 - 1160m Area = 0.05km^2 Aspect = E Terrain: Plane slope with small benches.	Year: Once in five years. Track season: Once in 30 years.
TRACK	COMMENTS
Slope = 49° Elevation = 1160 - 550m Terrain: Unconfined and rough.	Quite small and low elevation starting zone means that this is not a particularly dangerous path. Some problems could arise if photographic or sightseeing stops were made by the lakeside during or soon after storms.
RUN-OUT ZONE	
Slope = 14° Elevation = 550 - 520m Terrain: Edge of fan with small lake.	


MINTARO

21. MINTARO

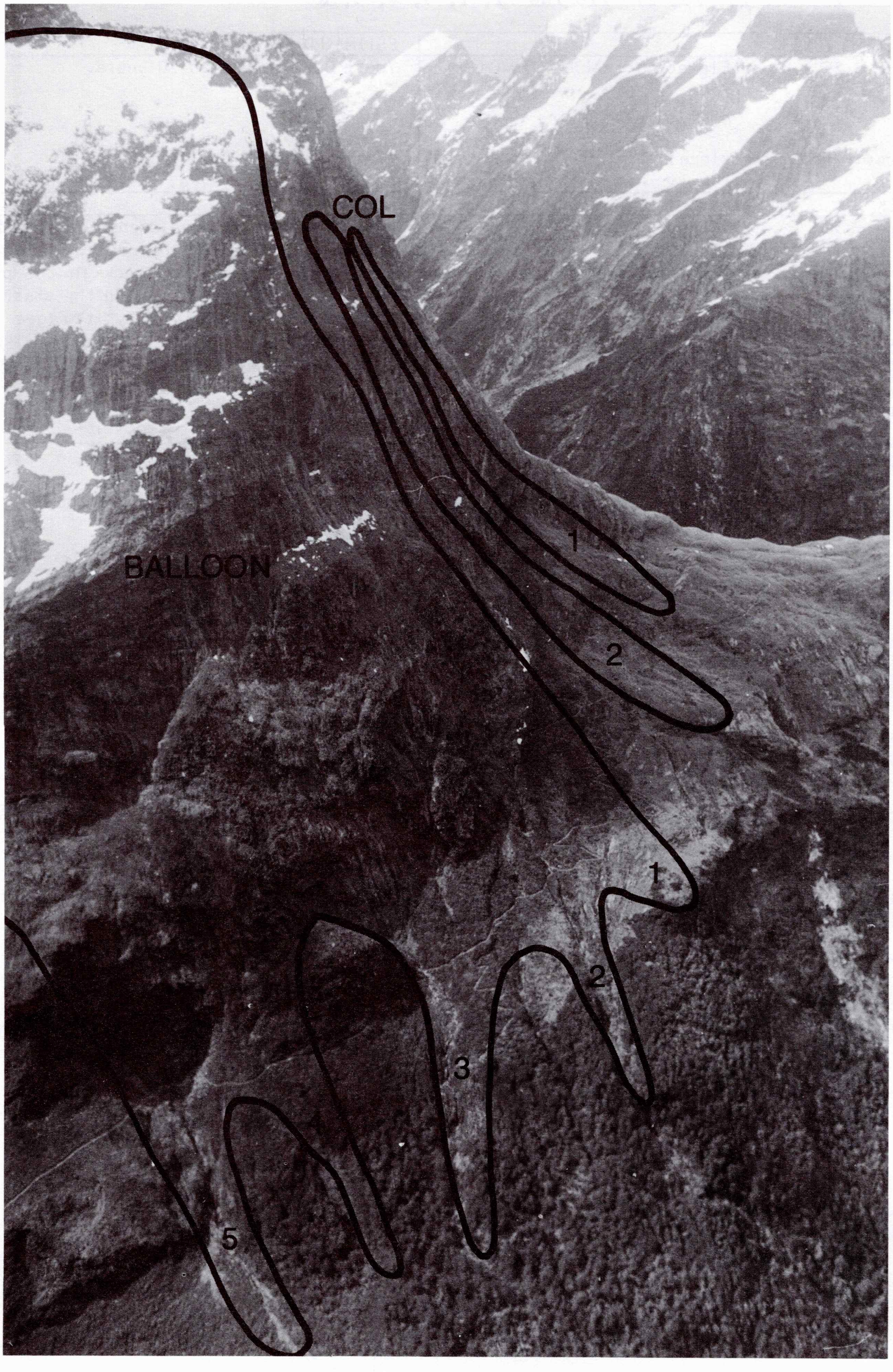
STARTING ZONE	ESTIMATED FREQUENCY
Slope = 59° Elevation = 1370-1010m Area = $0.08km^2$ Aspect = N Terrain: Steep rough slope.	Year: Once in 20 years. Track season: Once in 50 years.
TRACK	COMMENTS
Slope = 57° Elevation = 1010 - 640m Terrain: Unconfined.	A relatively small path with a steep starting zone suggesting that only small avalanches result, most probably in southerly storms. Because of the aspect, avalanches could also occur on warm days following snowfalls to low level.
RUN-OUT ZONE	
Slope = 10° Elevation = 640 - 610m Terrain: Small fan and river flat.	



Z1040

22, 23, 24, 25, 26, 27 ZIG ZAG 1, 2, 3, 4, 5, 6

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 25^{0} Elevation = 1130 - 1040m Area = $0.06km^{0}$ Aspect = 5 Terrain: Irregular slope.	Year: Once in 0.3 to 20 years. Track season: Once in 3 to 50 years.
TRACK	COMMENTS
Slope = 36^{0} Elevation = 1040 - 910m Terrain: Partially confined.	A series of small avalanches of variable frequency. It is dangerous because of the length of walking track in the path and because walkers crossing the starting zones could potentially trigger an avalanche. Lee slope loading is likely in northerly and north-westerly storms.
RUN-OUT ZONE	
Slope = 36^{0} Elevation = 910 - 670m Terrain: Steep gullies.	

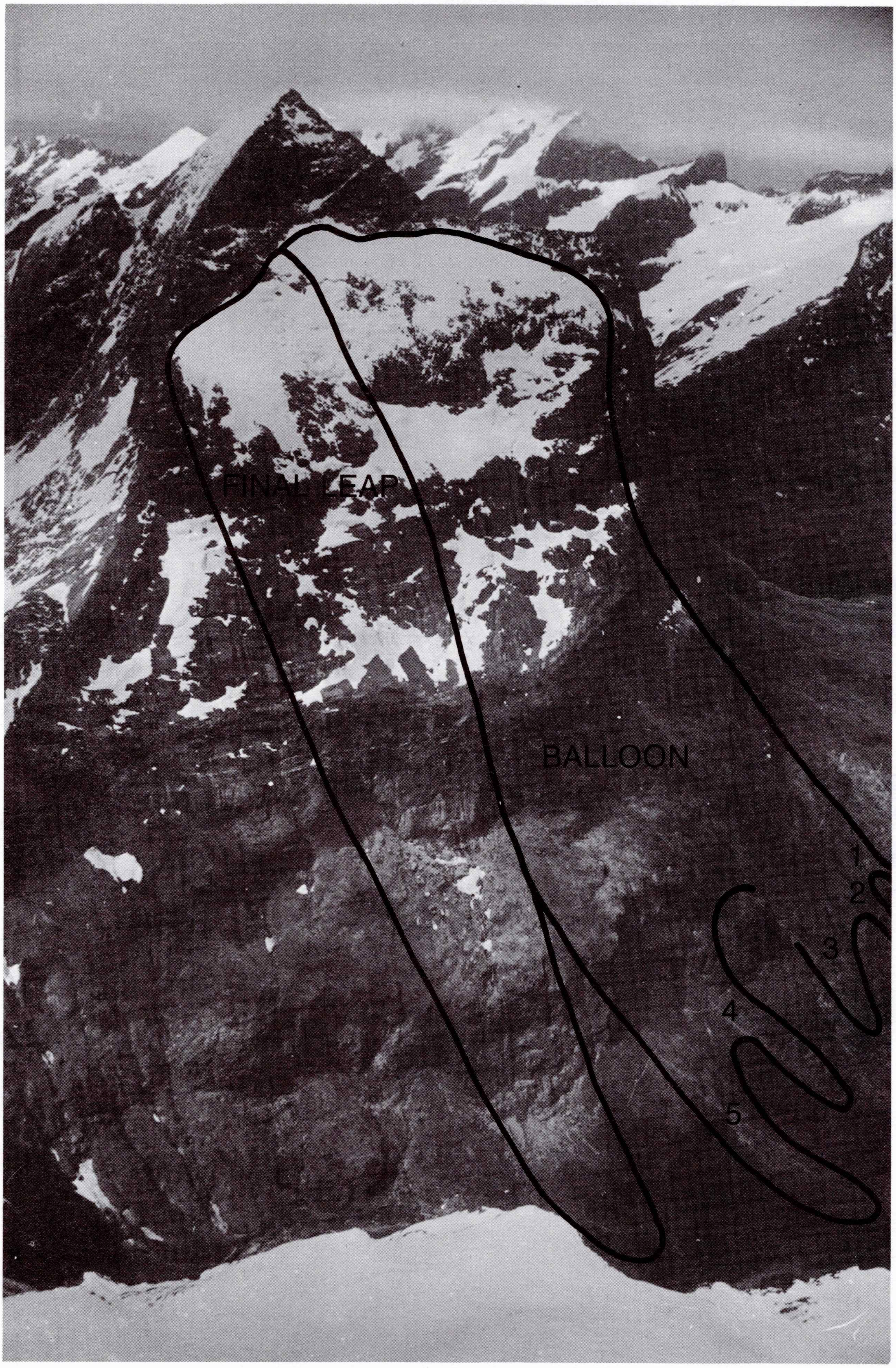

COL
BALLOON
1
2
1
2
3
5

28. COL 1

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 65^0 Elevation = 1460 - 1220m Area = $0.003km^2$ Aspect = WNW Terrain: Steep relatively smooth slope.	Year: Twenty per year. Track season: Once in 10 years.
TRACK	COMMENTS
Slope = 29^0 Elevation = 1220 - 1130m Terrain: Unconfined rough slope.	A very small path with a very steep starting zone. Reasonably high frequency.
RUN-OUT ZONE	
Slope = 31^0 Elevation = 1130 - 1040m Terrain: Steep slope.	

29. COL 2

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 69^0 Elevation = 1490 - 1190m Area = $0.01km^2$ Aspect = WNW Terrain: Steep relatively smooth slope.	Year: Twenty per year. Track season: Once in 10 years.
TRACK	COMMENTS
Slope = 39^0 Elevation = 1190 - 1100m Terrain: Unconfined rough slope.	Similar to COL 1. but slightly larger.
RUN-OUT ZONE	
Slope = 32^0 Elevation = 1100 - 980m Terrain: Steep slope.	

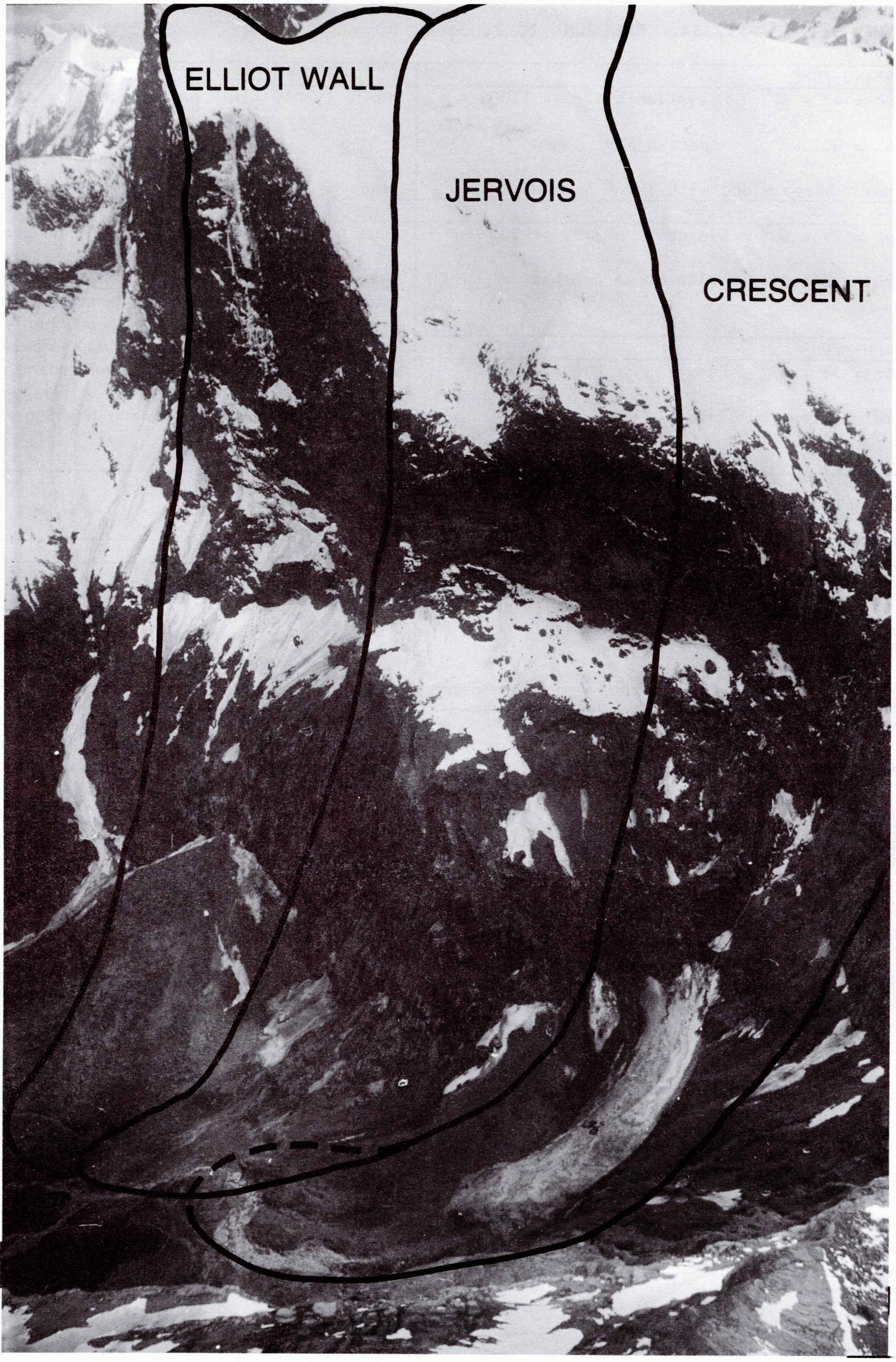

FINAL LEAP
BALLOON
1
2
3
4
5

30, 31, 32, 33, 34, BALLOON 1, 2, 3, 4, 5

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 43 - 62° Elevation = 1740 - 1100m Area = $0.20km^2$ Aspect = NNW Terrain: Steep slope with large benches.	Year: Twenty times per year. Track season: Once in 5 to 10 years.
TRACK	COMMENTS
Slope = 29 - 60° Elevation = 1430 - 990m Terrain: Unconfined with broad benches.	This series of paths is quite dangerous in parts. Although the average starting zone angle is very high, accumulation of snow occurs on the broad benches within the zone - especially after southerly or southwesterly storms. Avalanche release could be expected from overloading and probably more frequently from weakening of the snowpacts, following heating from solar radiation.
RUN-OUT ZONE	
Slope = 35 - 49° Elevation = 1100 - 730m Terrain: Steep gullies.	

35. FINAL LEAP

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 45o Elevation = 1710 - 1280m Area = $0.05km^2$ Aspect =	Year: Ten times per year. Track season: Once in 20 years.
TRACK	COMMENTS
Slope = 53° Elevation = 1280 - 940m Terrain: Unconfined with broad benches.	Similar to the Balloon paths, though probably slightly less active, and must run further to reach the walking track.
RUN-OUT ZONE	
Slope = 20° Elevation = 940 - 850m Terrain: Rockfall and avalanche debris fan.	


ELLIOT WALL
JERVOIS
CRESCENT

36. CRESCENT

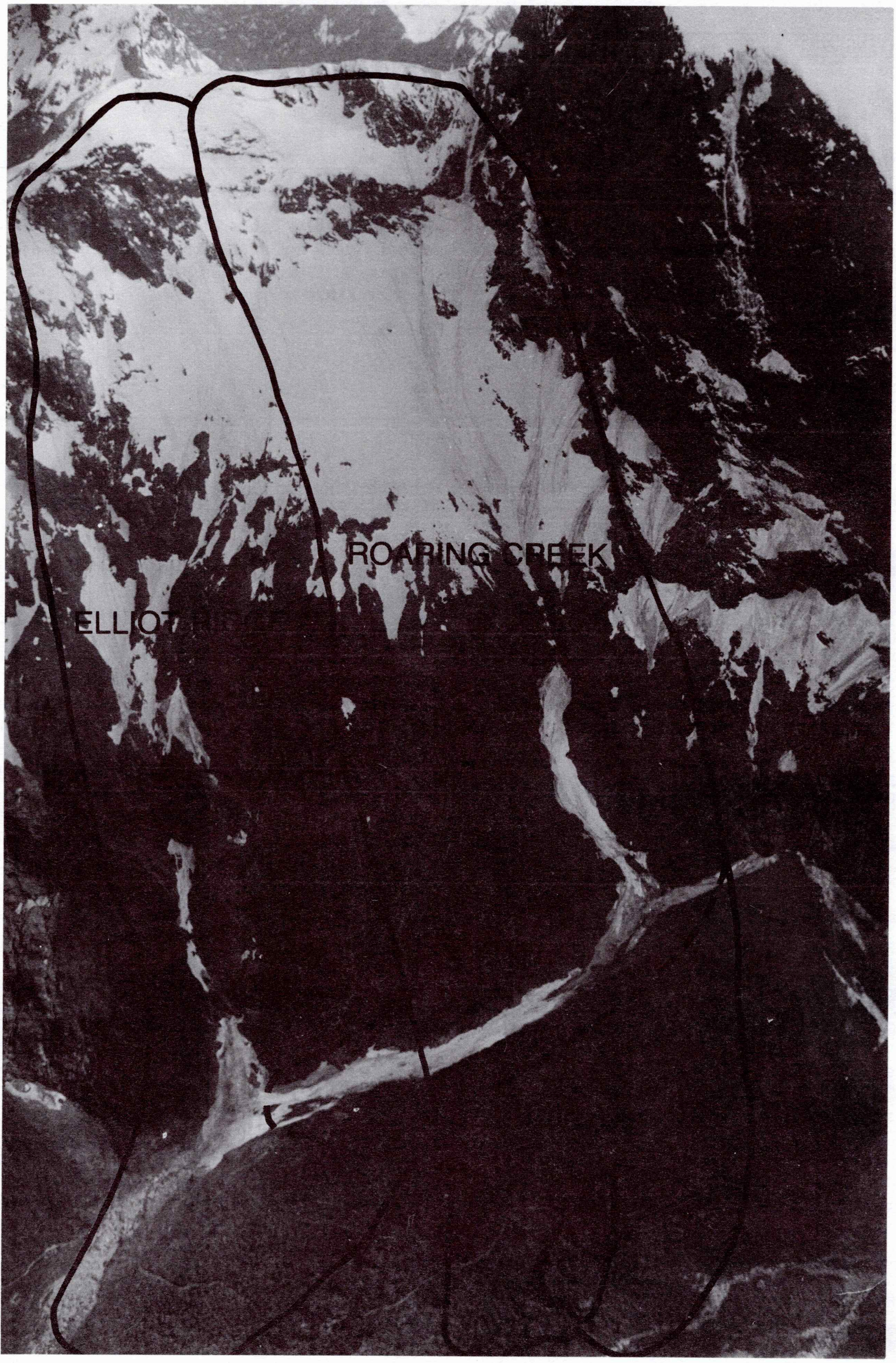
STARTING ZONE	ESTIMATED FREQUENCY
Slope = 37° Elevation = 1680 - 1220m Area = 0.26km^2 Aspect = SW Terrain: Plane slope with icefield.	Year: Once in 10 years. Track season: Once in 50 years.
TRACK	COMMENTS
Slope = 49° Elevation = 1220 - 980m Terrain: Steep, rough and partially confined.	An avalanche which clearly runs very frequently but has to traverse most of its run-out zone to reach the walking track. Most dangerous in north to northwest storms.
RUN-OUT ZONE	
Slope = 13° Elevation = 980 - 840m Terrain: Fan.	

37. JERVOIS

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 33° Elevation = 1830 - 1220m Area = 0.29km^2 Aspect = S Terrain: Broad slope with permanent icefield.	Year: Three times per year. Track season: Once in 10 years.
TRACK	COMMENTS
Slope = 56° Elevation = 1220 - 940 Terrain: Steep, unconfined with broad benches.	This path and the next represent the greatest danger on the Milford Track. They are particularly dangerous in windy northwest or westerly storms, as the starting zones on the Jervois Glacier are in the lee of the top ridge of Mt. Elliot. Such conditions led to a fatality in November 1982. Avalanches may also occur here, following pronounced warming or occurrence of rainfall at high elevations.
RUN-OUT ZONE	
Slope = 13° Elevation = 940 - 910 Terrain: Fan.	

38. ELLIOT WALL

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 45° Elevation = 1920 - 1590 Area = 0.19km^2 Aspect = S Terrain: Steep slope with permanent icefield.	Year: Three times per year. Track season: Once in 10 years.
TRACK	COMMENTS
Slope = 55° Elevation = 1590 - 950m Terrain: Steep with broad benches.	Similar to Jervois, but with slightly smaller and steeper starting zone. Fatality occurred here in November 1982.
RUN-OUT ZONE	
Slope = 12° Elevation = 950 - 820m Terrain: Fan.	

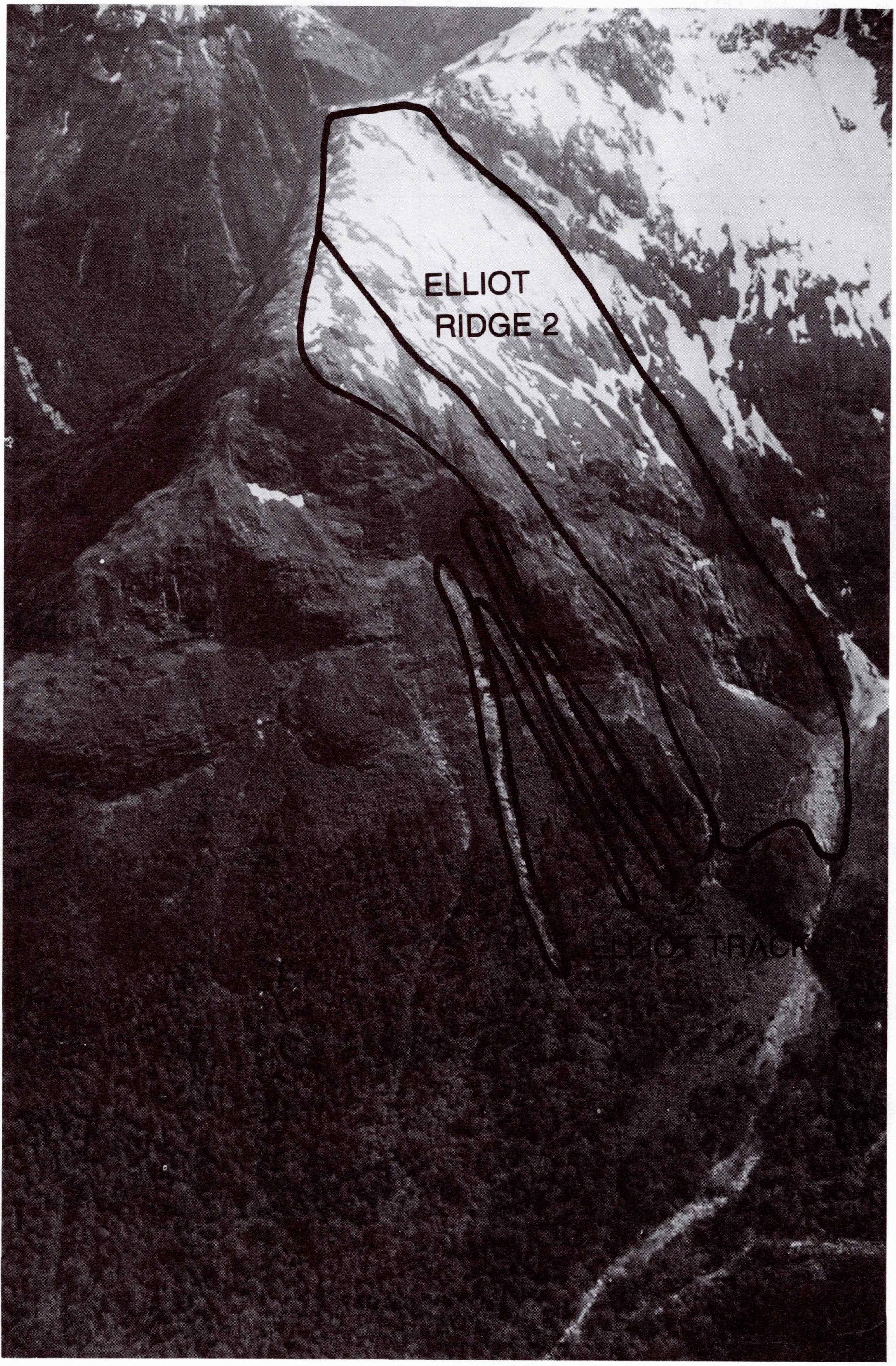

ROARING CREEK
ELLIOT RIDGE

39. ROARING CREEK

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 40° Elevation = 1590 - 1220m Area = 0.19km^2 Aspect = SE Terrain: Rough bowl with benches.	Year: Twice per year. Track season: Once every 10 years.
TRACK	COMMENTS
Slope = 34° Elevation = 1220 - 880m Terrain: Wide but confined.	A significant avalanche path, though small to moderate avalanches are diverted away from the walking track. Greatest danger might be expected from airborne avalanches, though these are less likely for storms loading the aspect.
RUN-OUT ZONE	
Slope = 14° Elevation = 880 - 730m Terrain: Partly gullied and fan material.	

40. ELLIOT RIDGE 1

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 43° Elevation = 1520 - 1130m Area = 0.11km^2 Aspect = SE Terrain: Steep broken slope.	Year: Once every 0.3 years. Track season: Once every 10 years.
TRACK	COMMENTS
Slope = 42° Elevation = 1130 - 820m Terrain: Rough and partially confined.	A smaller avalanche than the previous one, but can reach the walking track via Roaring Creek.
RUN-OUT ZONE	
Slope = 18° Elevation = 820 - 730m Terrain: Broad gully and fan.	


ELLIOT
RIDGE 2
2
ELLIOT TRACK

41. ELLIOT RIDGE 2

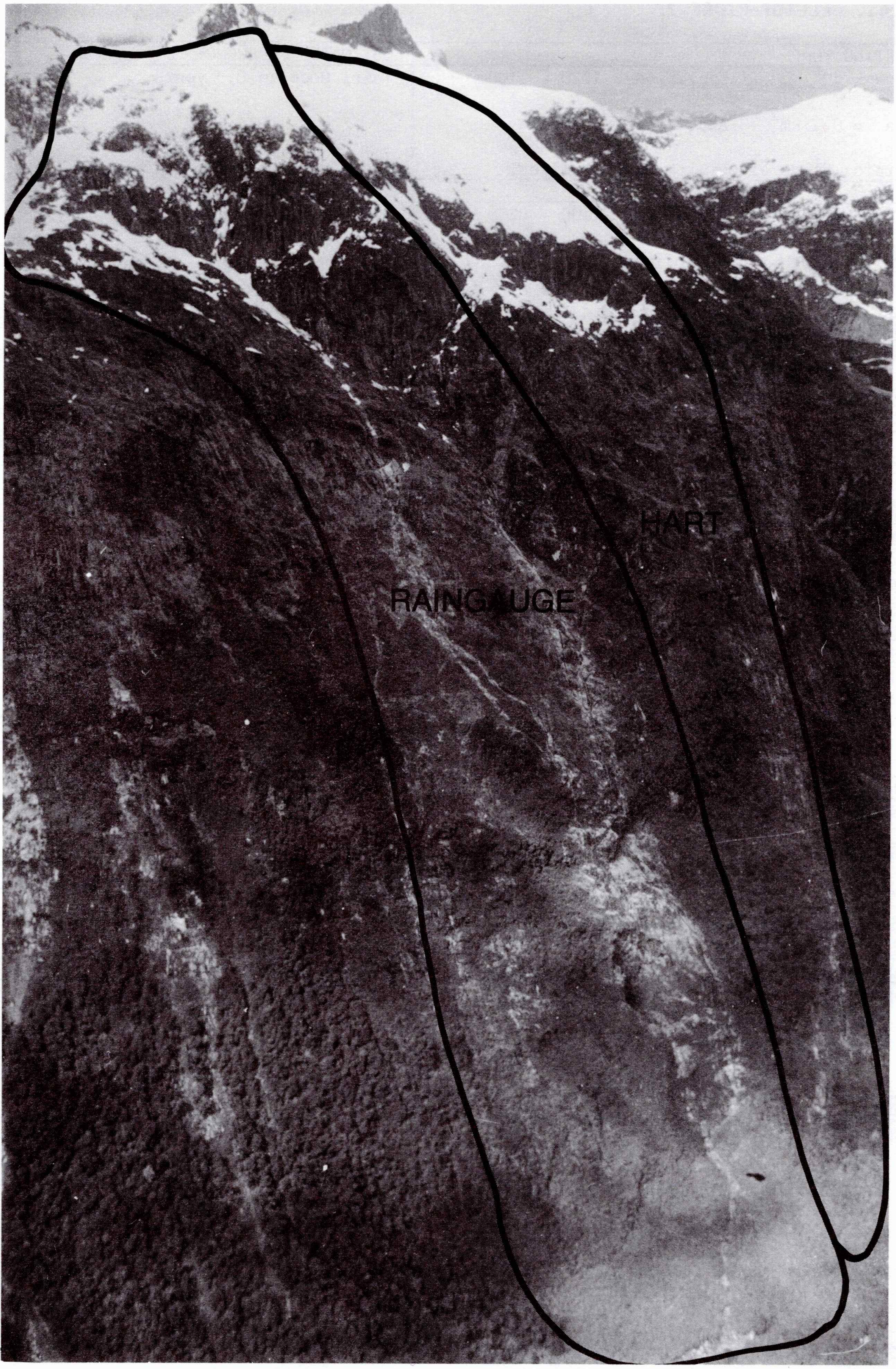
STARTING ZONE	ESTIMATED FREQUENCY
Slope = 40° Elevation = 1420 - 1100m Area = $0.11km^2$ Aspect = SE Terrain: Steep slope with small gullies.	Year: Once in 0.3 years. Track season: Once in 10 years.
TRACK	**COMMENTS**
Slope = 40° Elevation = 1100 - 820m Terrain: Rough and unconfined.	Similar to Elliot Ridge 1. which will run with wind directions from north to west.
RUN-OUT ZONE	
Slope = 23° Elevation = 820 - 700m Terrain: Fan and broad gully.	

42. ELLIOT TRACK 1

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 33° Elevation = 1310 - 1070m Area = $0.06km^2$ Aspect = SE Terrain: Plane slope with small irregularities.	Year: Once in 0.3 years. Track season: Once in 30 years.
TRACK	**COMMENTS**
Slope = 46° Elevation = 1070 - 760m Terrain: Steep unconfined slope.	A small track which, because of lower elevation of the starting zone, is not particularly important in the track season.
RUN-OUT ZONE	
Slope = 18° Elevation = 760 - 670m Terrain: Gully	

43, 44, 45, ELLIOT TRACK 2, 3, 4

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 45 - 57° Elevation = 1070 - 850m Area = $0.01km^2$ Aspect = SE Terrain: Steep gullies.	Year: Once in 0.3 to 10 years. Track season: Once in 30 years.
TRACK	**COMMENTS**
Slope = 36 - 43° Elevation = 910 - 730m Terrain: Confined.	Not very significant because of low elevation and small amount of track affected.
RUN-OUT ZONE	
Slope = 23 - 27° Elevation = 760 - 640m Terrain: Gullies.	

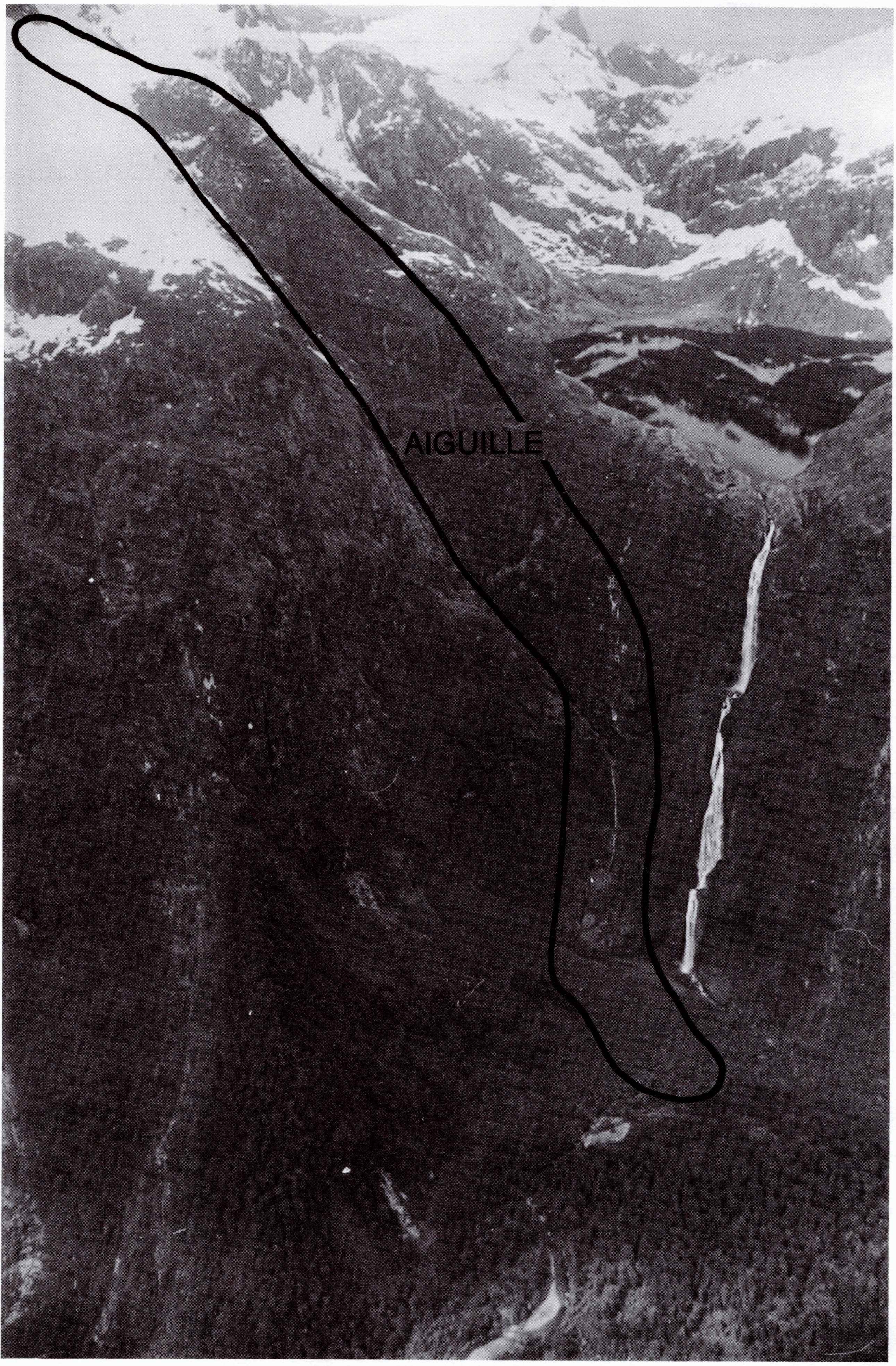

HART
RAINGAUGE

46. RAINGAUGE

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 49° Elevation = 1680 - 1370m Area = $0.18km^2$ Aspect = N Terrain: Rough bowl shape.	Year: Once in 20 years. Track season: Once in 30 years.
TRACK	COMMENTS
Slope = 50° Elevation = 1370 - 300m Terrain: Partially confined in upper section.	A relatively large path but not particularly active, especially in the track season. The starting zone is quite steep and rough. Affects quite a length of the track to Sutherland Falls.
RUN-OUT ZONE	
Slope = 6° Elevation = 300 - 260m Terrain: Fan.	

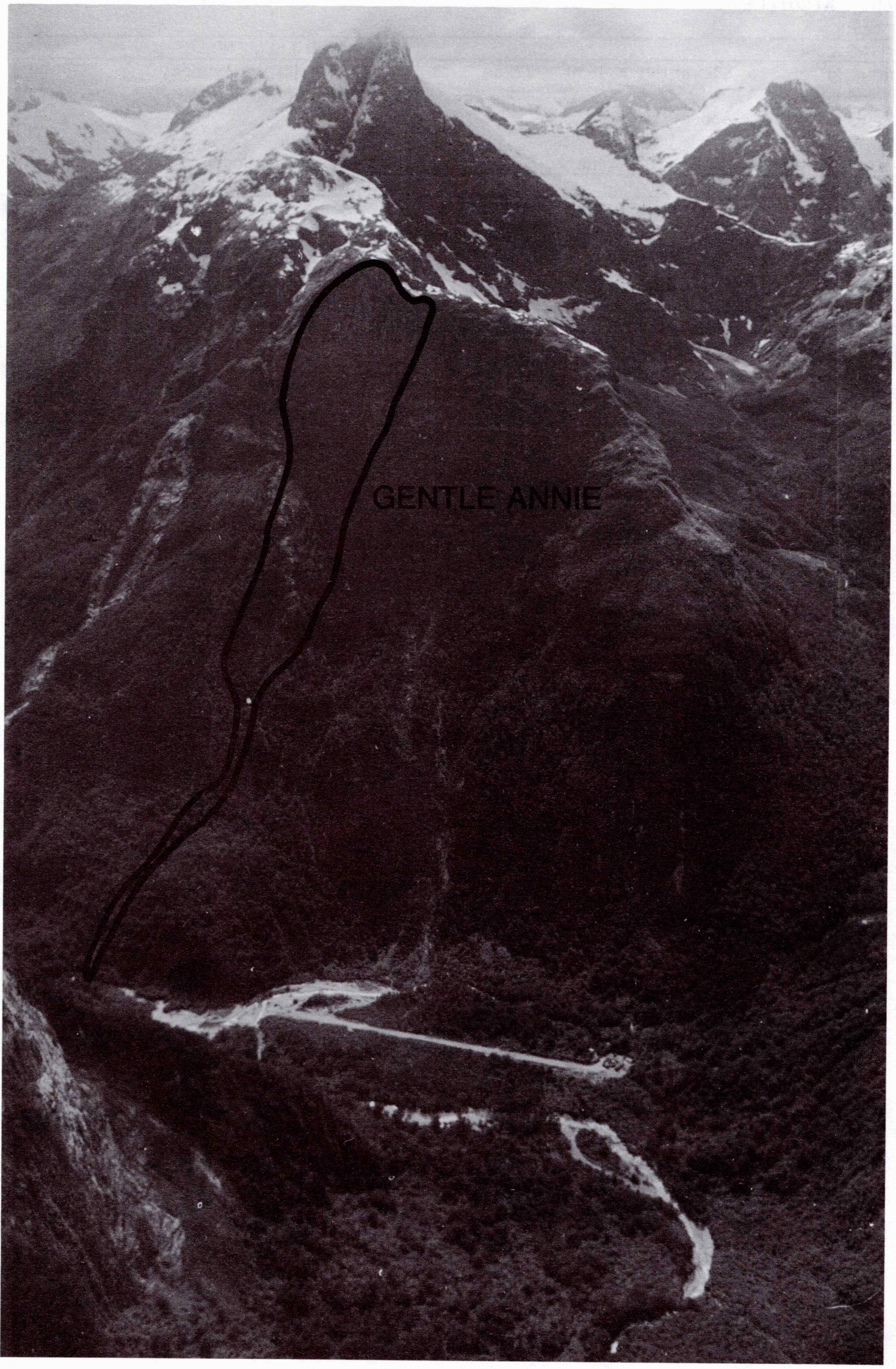
47. HART

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 29° Elevation = 1680 - 1370m Area = $0.13km^2$ Aspect = NNW Terrain: Plane relatively smooth slope.	Year: Once in 30 years. Track season: Once in 50 years.
TRACK	COMMENTS
Slope = 51° Elevation = 1370 - 400m Terrain: Steep unconfined.	Smaller path with a smooth, relatively low angled starting zone. Frequency of occurrence is quite low and affects a small part of the walking track.
RUN-OUT ZONE	
Slope = 29° Elevation = 400 - 290m Terrain: Fan.	


AIGUILLE

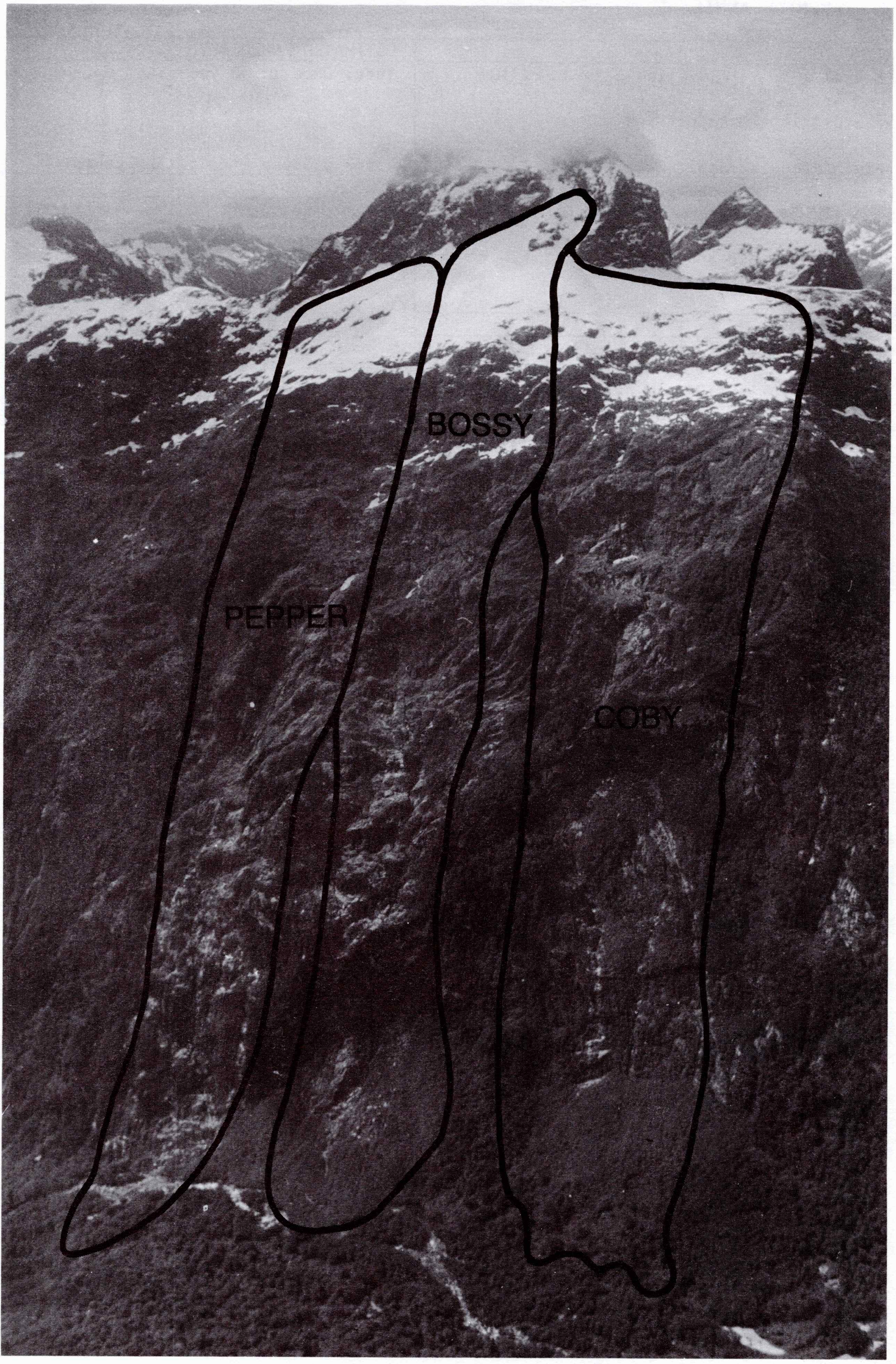
48. AIGUILLE

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 34° Elevation = 1680 - 1220m Area = 0.13km^2 Aspect = NW Terrain: Smooth shoulder of Mt. Hart.	Year: Once in 25 years. Track season: Once in 50 years.
TRACK	COMMENTS
Slope = 52° Elevation = 1220 - 430m Terrain: Steep and confined.	A steep curving path of limited significance. The danger here is probably increased by the fact that sightseers would tend to remain in this area to view and photograph the Falls.
RUN-OUT ZONE	
Slope = 15° Elevation = 430 - 360m Terrain: Fan.	


GENTLE ANNIE

49. GENTLE ANNIE

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 44° Elevation = 1590 - 1310m Area = $0.12km^2$ Aspect = W Terrain: Irregular bowl.	Year: Once in 50 years. Track season: Once in 100 years.
TRACK	COMMENTS
Slope = 42° Elevation = 1310 - 610m Terrain: Unconfined and rough.	An unimportant path, difficult to identify.
RUN-OUT ZONE	
Slope = 32° Elevation = 610 - 230m Terrain: Partly confined in lower part.	


BOSSY
PEPPER
COBY

50. COBY

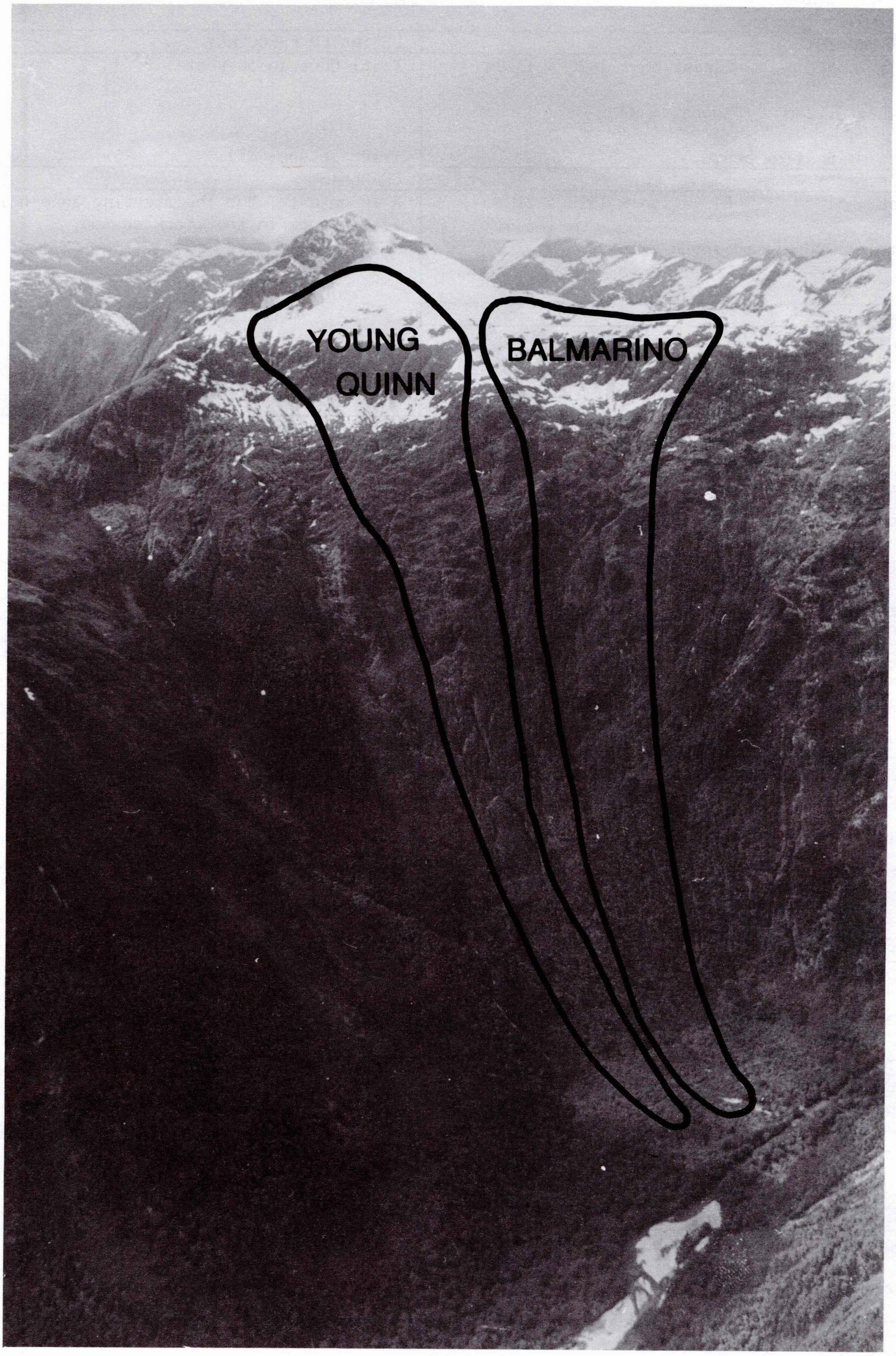
STARTING ZONE	ESTIMATED FREQUENCY
Slope = 35° Elevation = 1620 - 1310m Area = 0.22km^2 Aspect = NW Terrain: Shallow bench.	Year: Once in 50 years. Track season: Nil.
TRACK	COMMENTS
Slope = 51° Elevation = 1310 - 210m Terrain: Unconfined rough slope.	A large path, but the starting zone holds little snow in the track season.
RUN-OUT ZONE	
Slope = 20° Elevation = 210 - 90m Terrain: Vegetated fan.	

51. BOSSY

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 34° Elevation = 1680 - 1370m Area = 0.24km^2 Aspect = N Terrain: Plane slope with small benches.	Year: Once in 20 years. Track season: Nil.
TRACK	COMMENTS
Slope = 51° Elevation = 1370 - 150m Terrain: Unconfined and rough.	Similar to Coby but shows slightly greater activity in winter season.
RUN-OUT ZONE	
Slope = 31° Elevation = 150 - 60m Terrain: Partly vegetated fan.	

52. PEPPER

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 43° Elevation = 1680 - 1310m Area = 0.09km^2 Aspect = N Terrain: Shallow bowl.	Year: Once each year Track season: Once in 5 years
TRACK	COMMENTS
Slope = 47° Elevation = 1310 - 180m Terrain: Unconfined.	Elevation and aspect cause low snow-holding capability, but avalanche plunges onto track which is confined by the river.
RUN-OUT ZONE	
Slope = 19° Elevation = 180 - 60m Terrain: Vegetated fan.	

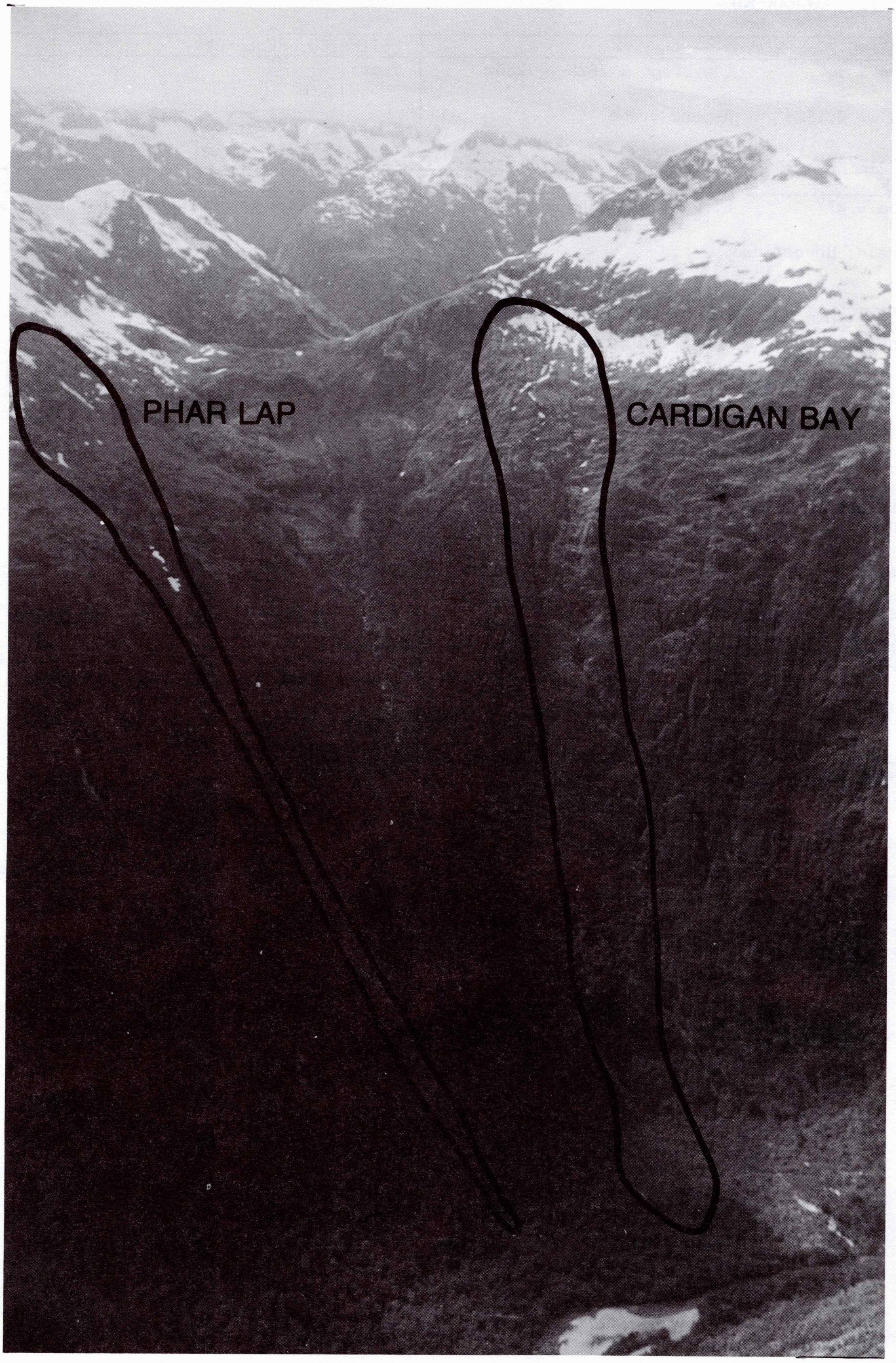

YOUNG
QUINN
BALMARINO

53. BALMARINO

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 34° Elevation = 1620 - 1280m Area = 0.25km^2 Aspect = WNW Terrain: Bowl with steep bench.	Year: Track season:
TRACK	COMMENTS
Slope = 47° Elevation = 1280 - 180m Terrain: Unconfined.	Relatively unimportant; elevation and aspect cause low snow-holding capability.
RUN-OUT ZONE	
Slope = 20° Elevation = 180 - 60m Terrain: Vegetated fan.	

54. YOUNG QUINN

STARTING ZONE	ESTIMATED FREQUENCY
Slope = 45° Elevation = 1680 - 1220m Area = 0.18km^2 Aspect = NW Terrain: Broad benches.	Year: Once in 20 years. Track season: Nil.
TRACK	COMMENTS
Slope = 44° Elevation = 1220 - 150m Terrain: Unconfined.	Relatively unimportant; elevation and aspect cause low snow-holding capability.
RUN-OUT ZONE	
Slope = 17° Elevation = 150 - 60m Terrain: Vegetated fan.	


PHAR LAP
CARDIGAN BAY

55. CARDIGAN BAY

STARTING ZONE

Slope = 47° Elevation = 1490 - 980m

Area = 0.18km^2 Aspect = W

Terrain: Steep slope.

TRACK

Slope = 40° Elevation = 980 - 150m

Terrain: Unconfined.

RUN-OUT ZONE

Slope = 23° Elevation = 150 - 60m

Terrain: Vegetated fan.

ESTIMATED FREQUENCY

Year: Once in 10 years.

Track season: Nil.

COMMENTS

Relatively unimportant; elevation and aspect cause low snow-holding capability.

56. PHAR LAP

STARTING ZONE

Slope = 39° Elevation = 1370 - 1040m

Area = 0.19km^2 Aspect = WSW

Terrain: Plane slope.

TRACK

Slope = 39° Elevation = 1040 - 60m

Terrain: Partially confined.

RUN-OUT ZONE

Slope = 3° Elevation = 60 - 50m

Terrain: Small fan.

ESTIMATED FREQUENCY

Year: Once in 30 years.

Track season: Nil.

COMMENTS

Relatively unimportant; elevation and aspect cause low snow-holding capability.